

## **Historic, Archive Document**

Do not assume content reflects current scientific knowledge, policies, or practices.



aTP295

.T67

1992

United States  
Department of  
Agriculture

Forest Service

Technology &  
Development  
Program

7100-Engineering  
April 1992  
9271-2815-MTDC



# Guide for Using, Storing, and Transporting Explosives and Blasting Materials



**United States  
Department of  
Agriculture**

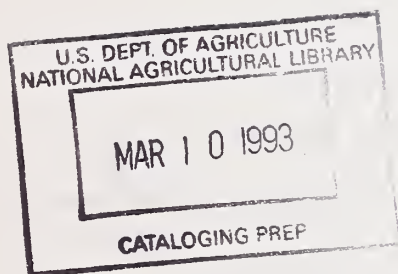


**National Agricultural Library**

The Forest Service, U.S. Department of Agriculture has developed this information for the guidance of its employees, its contractors, and its cooperating Federal and State agencies, and is not responsible for the interpretation or use of this information by anyone except its own employees.

The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader and does not constitute an endorsement by the U.S. Department of Agriculture of any product or service to the exclusion of others that may be suitable.

# Guide for Using, Storing, and Transporting Explosives and Blasting Materials



James W. Tour  
*Mechanical Engineer*

Technology & Development Program  
Missoula, Montana 59801

TE02L14  
Technical Services—Explosives

April 1992

USDA, National Agricultural Library  
NAL Bldg  
10301 Baltimore Blvd  
Beltsville, MD 20705-2351

# Contents

---

## Chapter 1—General Requirements.....1

- 1.1 General .....1
- 1.2 Inspection .....1
- 1.3 Records .....8

## Chapter 2—Explosives.....13

- 2.1 Explosives .....13
- 2.2 Properties Of Explosives .....15
- 2.3 Blasting Agents and Ammonium Nitrate .....18
- 2.4 Nitroglycerin .....22
- 2.5 Two-Component Cap-Sensitive Explosives .....22
- 2.6 Military Explosives .....22
- 2.7 Initiating Devices .....23

## Chapter 3—Storage .....27

- 3.1 General .....27
- 3.2 Storing Explosives In Remote, Uninhabited, Roadless Locations .....27
- 3.3 Storing Fireline Explosives In The Field.....27
- 3.4 Two-Component Cap-Sensitive Explosives .....27
- 3.5 Permanent Magazine .....27

## Chapter 4—Transportation .....39

- 4.1 General .....39
- 4.2 Transporting Explosives By Motor Vehicle .....39
- 4.3 Transporting Explosives With Pack Stock .....52
- 4.4 Transporting Explosives With Trail Vehicles and ATV's .....53
- 4.5 Transporting Explosives By Vessel.....53
- 4.6 Transporting Explosives By Aircraft .....53

## Chapter 5—Use .....59

- 5.1 Signing .....59
- 5.2 Initiation .....60
- 5.3 Misfires .....66
- 5.4 Disposing of Deteriorated or Damaged Explosives .....67
- 5.5 Blast Design .....68
- 5.6 Ground Vibration and Airblast .....75

## Chapter 6—Specialized Blasting Techniques .....79

- 6.1 Avalanche Blasting .....81
- 6.2 Fireline Explosives .....93
- 6.3 Burnol' Backfiring Devices.....105
- 6.4 Seismic Blasting .....107

# Foreword

---

This guide for Forest Service Blaster Examiners and Blasters presents *minimum* requirements for using, storing, and transporting explosives and blasting materials. These requirements are essential to insure that blasting activities are accomplished safely and to prevent theft of explosive materials. The guide consolidates information needed to conduct normal Forest Service operations into one guide. It is not intended to be all inclusive. There are many other supporting documents that should be referred to by Forest Service blasters.

Information for this guide was gathered from industry handbooks, other literature, The Institute of Makers of Explosive publications, Federal regulations, and the *Blasters' Handbook*, revised November 1989, by Austin A. Dickinson, Pacific NW Regional Blaster Examiner (Retired).

# References

The following materials should be accessible to all Blasters and Blaster Examiners.

1. **USDA Forest Service Manual, 6760 Special Safety and Health Activities; 6761 Blasting and Explosives** (In Preparation):

- 6761.01 Authority;
  - (a) Use;
  - (b) Storage;
  - (c) Transportation;
  - (d) Disposal;
- 6761.02 Objectives;
- 6761.03 Policy;
- 6761.04 Responsibilities

2. **Blasters' Handbook.** (Current edition.) E.T. duPont deNemours & Co., Wilmington, Delaware 19898.

3. **State laws and regulations.**

4. **Federal laws and regulations.** Federal regulations controlling transportation, storage, and use are listed below. The regulations most commonly applicable to Forest Service activities are included:

**Title 27 CFR, Part 55,** Commerce in Explosives, with emphasis on Subpart K, Storage, Bureau of Alcohol, Tobacco, and Firearms. (BATF), U.S. Government Printing Office, Washington, D.C., 20402

**Title 29 CFR, Subparts H 1910.109 and U 19926.900.** Occupational Safety and Health Administration (OSHA), U.S. Government Printing Office, Washington, D.C. 20402.

**Title 30 CFR, Part 55,** Mine Safety and Health Administration (MSHA) Department of Labor, U.S. Government Printing Office, Washington, D.C., 20402.

**Title 49, CFR, parts 171-177 and 390-397,** Department of Transportation, (DOT), U.S. Government Printing Office, Washington, D.C., 20402.

5. **Handbook of Electric Blasting,** 1976. Revised by Atlas Chemical Industries, Explosives Division, Wilmington, Delaware 19899.

6. **Primacord Handbook,** 1984. Ensign-Bickford Co., Simsbury, CT 06070.

7. **Safety Fuse—What It Is, How To Use It,** 1972. Ensign-Bickford Co., Simsbury, Connecticut 06070.

8. **Uses of Explosives in Seismic Exploration,** 1974. Neil MacDonald, Atlas Powder Co., Southland Center, Dallas, Texas 75251.

9. **Avalanche Handbook,** Agriculture Handbook 489. July 1976. Slightly revised Nov. 1978 by Alpine Snow and Avalanche Research Project, Rocky Mountain Forest And Range Experiment Station, USDA Forest Service, – Fort Collins, Colorado. (Out of print, but commonly used.)

10. **Institute of Makers of Explosives Publications,** Nos. 2,4,17, 20, and 22, 4230 Lexington Ave., New York, New York 10017.

11. **Can Static Electricity From Clothing Detonate Electric Blasting Caps,** 1971. USDA Forest Service Equip Tips, Missoula Technology and Development Center, Bldg. 1, Fort Missoula, Missoula, Montana 59801.

12. **Blasting Near High Voltage Powerlines,** 1974. Atlas Powder Co., Southland Center, Dallas, Texas 75203.

13. **National Fire Protection Association Standard No. 78.** Batterymarch Park, Quincy, MA 02269.

14. **Blasting Techniques: 1. Estimating the Blasting Project,** 1985. Albert E. Teller, P.O. Box 664, Issaquah, Washington 98027.

15. **Blasting Techniques: 2. Ditches-Stumps-Boulders,** 1983. Albert E. Teller, P.O. Box 664, Issaquah, Washington 98027.

16. **Unified Rock Classification System.** Douglas Williamson, Engineering Geologist, USDA Forest Service, Region 6, P.O. Box 3623, Portland, OR 97208.

17. **Explosives and Rock Blasting.** 1987. Atlas Powder Company. 15301 Dallas Parkway, Suite 1200, Dallas, Texas 75248.

18. **Drivers Pocket Guide to Hazardous Materials.** 1989. J.J. Keller & Associates, Inc. Sixth Edition, P.O. Box 368, Neenah, Wisconsin 54957-0368.

# Acknowledgments

---

Acknowledgment is made to Albert E. Teller for his permission to use portions of his book, *Blasting Techniques 1*, which appear in Chapter 50.

Acknowledgment is also made to Douglas Williamson for use of portions of his paper, *Unified Rock Classification System*, which are also included in Chapter 50. Both are included in the list of references and are valuable additions to the library of any blaster.

This guide is the product of many experienced hands. Numerous individuals assisted with the preparation of this Guide in a variety of ways. Special acknowledgment is due to the following:

- **Mike Knodel**, Northern Region, Blaster Examiner
- **F. Marion Morrill**, Intermountain Region, Blaster Examiner (Retired)
- **Robbie Watson**, Pacific Northwest Region, Blaster Examiner
- **Austin A. Dickinson**, Pacific Northwest Region, Regional Blaster Examiner (Retired)
- **James R. Lott**, Missoula Technology & Development Center (Deceased)

# Definitions

---

## **Approved Explosives.**

Explosives approved by Regional Forester for Regional use.

**Approved Storage Facility (Approved Magazine).** A facility for the storage of explosive materials conforming to the requirements in *Title 27 CFR, Part 55, Explosive Materials Regulations, Subpart K, Storage*; Bureau of Alcohol, Tobacco, and Firearms (BATF).

**Back Break.** Rock broken beyond the limits of the last row of blast holes.

**Bench.** Horizontal ledge in a quarry face along which holes are drilled vertically. Benching is the process of excavating whereby terraces or ledges are worked in a stepped shape.

**Blasting Agent.** Any material or mixture of fuel and oxidizer used for blasting, but not otherwise defined as an explosive, that cannot be detonated with a No. 8 test blasting cap when unconfined. A common blasting agent currently in use is a mixture of ammonium nitrate and fuel oil. Use only premixed and packaged blasting agents from explosives companies or two component kinpack or kinestick.

**Blasting Galvanometer (Multimeter).** An electrical resistance instrument designed specifically for testing electric detonators and circuits containing them. Along with blasters' ohmmeters and blasters' multimeters, it is used to measure resistance or to check electrical continuity.

**Block Hole.** A hole drilled into a boulder to allow placement of a small charge to break the boulder.

**Booster.** An explosive charge, usually of high velocity and density, used to improve the initiation of less sensitive explosive materials.

**Bootleg.** The portion of a borehole that remains relatively intact after being charged with explosive and fired. (The blast fails to cause breakage.)

**Borehole.** A hole drilled in rock or other material for placement of explosives. Also known as blasthole.

**Bridging.** Where a column of explosives in a borehole is broken, either by improper placement or, as in the case of slurries or poured blasting agents, where some foreign matter has plugged the hole.

**Burden.** The distance from an explosive charge to the nearest free or open face. Technically, there may be an apparent burden and a true burden. The true burden is always measured in the direction displaced broken rock will occur after firing.

**Bus Wire.** Solid core 10,12, or 14 gauge uninsulated copper wire.

**Charge.** Explosive load in a hole.

**Collar.** Borehole mouth or opening. To collar means the act of starting a borehole.

**Condenser Discharge Blasting Machine.** Blasting machine that uses batteries or generator to

energize a series of condensers whose stored energy is released into a blasting circuit.

**Connecting Wire.** Any wire in a blasting circuit connecting leg wires with lead wire.

**Coupling.** Degree to which an explosive fills the borehole. Bulkloaded explosives are completely coupled. Untamped cartridges are uncoupled. (Also an intimate contact between explosives and rock.)

**Critical Diameter.** The minimum diameter for propagation of a detonation wave at a stable velocity. Critical diameter is affected by conditions of confinement, temperature, and pressure on the explosive.

**Cutoff.** Occurs when a column of explosives fails to detonate due to bridging or to a shifting of the rock formation caused by an improper delay system.

**Deck.** An explosive charge that is separated from the main charge by stemming or air cushion.

**Deflagration.** An explosive reaction such as a rapid combustion that moves through an explosive material at a velocity less than the speed of sound in the material.

**Delay Element.** That portion of a blasting cap causing a delay between the instant of application of electrical energy to the cap and the time the cap's base charge detonates.

**Density.** The mass of an explosive per unit volume, usually expressed in grams per cubic centimeter.

**Detonating Cord.** A flexible cord containing a center core of high explosives and used to initiate other explosives.

**Detonation.** An explosive reaction or shockwave that moves through an explosive material faster than the speed of sound in the material.

**Detonation Pressure.** The pressure produced in the reaction zone of a detonating explosive.

**Detonation Velocity.** The velocity at which a detonation progresses through an explosive.

**Detonator.** Any device containing any initiating or primary explosive that is used for initiating detonation. A detonator may not contain more than 10 grams of total explosives by weight, excluding ignition or delay charges. The term includes, but is not limited to, electric blasting caps of instantaneous and delay types, blasting caps for use with safety fuses, detonating cord delay connectors, and nonelectric instantaneous and delay blasting caps that use detonating cord, shock tube, or any other replacement for electric legwires.

**Dynamite.** A high explosive used for blasting, consisting essentially of a mixture of, but not limited to, nitroglycerin, nitrocellulose, ammonium nitrate, and carbonaceous materials.

**Emulsion.** An explosive material containing substantial amounts of oxidizers dissolved in water droplets, surrounded by an immiscible fuel.

**Explosion.** Thermochemical process in which mixtures of gases, solids, or liquids react with the almost instantaneous formation of gaseous pressures and sudden heat release.

### **Explosive Materials.**

a. Any chemical compound, mixture, or device, that functions by the instantaneous release of gas and heat, unless such compound, mixture, or device is otherwise specifically classified by the Department of Transportation (DOT).

b. The Department of Transportation classifies material as class A, B, or C explosives.

**1. Class A Explosives.**  
*Possessing detonating hazard, such as dynamite, nitroglycerin, picric acid, lead azide, fulminate of mercury, black powder, detonating primers and detonators in excess of 1000.*

**2. Class B Explosives.**  
*Possessing flammable hazard, such as propellant explosives, including some smokeless propellants.*

**3. Class C Explosives.**  
*Including certain types of manufactured articles that contain class A or class B explosives, or both, as components but in small quantities such as detonators (less than 1000).*

**Extraneous Electricity.** Electrical energy, other than actual firing current or the test current from a blasting galvanometer, that is present at a blast site and that could enter an electric blasting

circuit. It includes stray current, static electricity, RF (electromagnetic) waves, and time-varying electric and magnetic fields.

**Flyrock.** Rocks propelled from the blast area by the force of an explosion.

**Low Explosives.** Explosive materials not bullet-sensitive, but which can be deflagrated when confined. For example, safety fuses, igniters, igniter cords, fuse lighters, and special fireworks, defined as class B explosives by Department of Transportation regulations in 49 *CFR, part 173.88(d)*.

**Mass Detonate.** Explosive materials mass detonate (mass explode) when a unit or any part of a larger quantity of explosive material explodes and causes all or a substantial part of the remaining material to detonate or explode simultaneously. With respect to detonators, "a substantial part" means 90 percent or more.

**Mat.** Used to cover a shot to hold down flying material, usually made of woven wire, cable, or rope.

**Millisecond Delay Caps.** Electric caps that have a built-in delay element, usually 0.025 second apart, consecutively. (Timing may vary with manufacturer).

**Mistire.** A blast that fails to detonate completely after an attempt at initiation; also the explosive material itself fails to detonate as planned.

---

**Mud Capping.** Sometimes known as bulldozing, adobe blasting, or dobying. Blasting boulders by placing a quantity of explosives against a rock, usually on top of a boulder or other object without confining the explosives in a drilled hole and covering it with clay or mud.

**Overbreak.** Excessive breakage of rock beyond the desired excavation limit.

**Overburden.** Material lying on top of the rock to be shot; usually refers to dirt and gravel, but can mean another type of rock, such as shale over limestone.

**Powder.** A common synonym for explosive material.

**Powder Factor.** The amount of explosive used per unit of rock, expressed as pounds of explosives per cubic yard of rock.

**Premature.** Charge detonates before it is intended to.

**Primer.** A unit, package, or cartridge of explosives used to initiate other explosives or blasting agents, and which contains: (1) a detonator; or (2) detonating cord to which is attached a detonator designed to initiate the detonating cord.

**Resistance.** The difficulty in causing current to flow in an electrical circuit (measured in ohms).

**Series Circuit.** An electric blasting circuit that provides one continuous path for the current through all caps in the circuit.

**Series Parallel Circuit.** An electric blasting circuit in which the ends of two or more series of electric detonators are connected across the firing line directly or through bus wire.

**Shunt.** The shorting together of the free ends of: (1) electric detonator legwires; or (2) the wire ends of an electric blasting circuit or part thereof; the name of an electrical shorting device applied to the free ends of electric detonators by the manufacturer.

**Spacing.** The distance between boreholes or charges in a row.

**Static Electricity.** Electric charge at rest on a person or object that can discharge across an air gap. It is most often produced by the contact and separation of dissimilar insulating materials.

**Stemming.** Inert material, such as drill cuttings, put in the collar (or elsewhere) of a borehole to confine the gaseous products formed by the explosion. Also, the length of borehole left uncharged.

**Stray Current.** A flow of electricity outside an insulated conductor system.

**Sub-drill.** The portion of the borehole that is drilled and loaded below design grade to insure that rock will be broken at grade.

**Sympathetic Detonation.** The detonation of an explosive material as the result of receiving an impulse from another detonation through air, earth, or water.

**Tamping.** The process of compressing the stemming or explosive in a borehole.

**Toe.** In bench blasting, the distance from the free face to the blasthole, measured at the floor level of the bench.

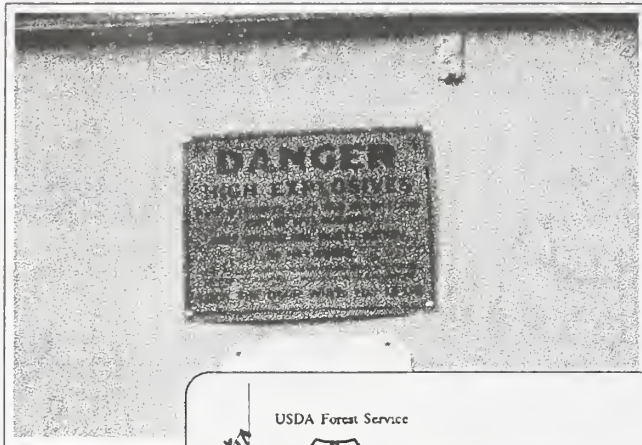
**VOD: Velocity of Detonation.** The speed at which an explosive will change from a chemical or solid state to a gaseous state.

**VOS: Sonic Velocity.** The speed at which an accoustical "shock" wave will travel through a homogenous rock mass.

**Water Gel.** An explosive material containing substantial portions of water, oxidizers, and fuel, plus a cross-linking agent.

---

# Chapter 1



USDA Forest Service

**FOREST BLASTER/GENERAL BLASTER'S CERTIFICATE**

*Joseph Blaster* <sup>11/92</sup>  
Date of Issue

certified for a period of 3 years from the date of issue to engage in those elements of explosive work which are initiated by the Regional Blaster Examiner on the reverse side of this card.

*Bob O'Neil*  
Recommended - Regional Blaster Examiner

*Jack Pine*  
Approved - Forest Supervisor

State Permit No. \_\_\_\_\_

FS-6700 27

... competence in those phases of explosive work as set forth in the Blaster's Guide and in Federal-State-Local regulations

Work Authorized	Initials
1 Blaster-In-Training/Blaster Inspector	
Store and Transport only	
LEVEL 1 Load, wire, test, shoot 10 holes with EBC's or det cord Load, wire, test, shoot stumps (S), ditching (DO).	
Clear cutlines	
Destroy abandoned explosives	
Use delays, EBC's or det cord type	
Use #20 duplex solid copper firing line	
Use Non-Electric Firing Line and Detonator	
Use Fuzing, Redgum system	
LEVEL 3 Load, wire, test, shoot 40 holes with EBC's or det cord Load, wire, test shoot stumps, ditching	
Forest Load Blaster/Blaster Examiner	
LEVEL 4 Fully qualified all phases of general blasting	
Specialty Blasting	
Specialty	
Other	
Other	

# Chapter 1—General Requirements

## Section Contents

<b>1.1 General</b>	<b>1</b>
<b>1.2 Inspection</b>	<b>1</b>
1.2.1 Explosive Materials In Storage	1
1.2.2 Magazine Condition	4
<b>1.3 Records</b>	<b>8</b>

## 1.1 General

All force account work with explosives shall be under the direct supervision of a qualified blaster who holds a current Forest Service Blaster's certificate. The certificate shall specify the type of blasting qualifications, such as construction, avalanche, seismic, and fireline. Transportation, use, mixing of component explosives, storage, magazine inspection, and disposal shall be done by or under the direct supervision of a certified blaster. For training and certification of blasters, see *FSM 6760*. For avalanche control by hand-placed explosives or projectiles, see *Avalanche Handbook (Agriculture Handbook 489), Chapter 6, Control by Explosives*. When two or more blasters are working together, one shall be the Blaster-In-Charge designated either by the supervisor or the blasters themselves.

Comply with Federal, State, and local laws as applicable. Use the most stringent regulation when a difference appears. Federal regulations controlling transportation, storage, and use are listed references.

Warn residents in or near blasting areas well in advance (at least 24 hours) of actual blasting. Post flaggers or signs or verbally warn others of

blasting operations. A seasonal or continuing notice is adequate for recurring work, such as for avalanche control.

When blasting in the vicinity of oil, gas, electric, fire alarm, telegraph, and steam utilities, notify representatives of such utilities at least 24 hours in advance of blasting. Specify the location and intended time of such blasting. Confirm verbal notice in writing. For recurring work in a relatively confined area, such as for avalanche control, written notice before the period or season is adequate. In an emergency, this time limit may be waived by the Regional Blaster Examiner.

When blasting in congested areas or near railways, highways, or other structures that may be damaged, take special precautions in the loading, delaying, and initiation of explosives. Confine each blast with mats or other methods to control fragments, airblasts, and vibration. If necessary, obtain assistance from the Regional Blaster Examiner or other qualified persons.

Prohibit smoking, firearms, matches, open-flame lamps, and other fires, flames, or heat-producing devices, and sparks within 50 feet of explosive magazines or while explosives are being handled, transported, or used.

Allow no one to handle explosives while under the influence of liquor, narcotics, or prescription drugs that impair performance.

Never abandon explosives, ammunition, or blasting agents.

Never fight a fire that is in imminent danger of contacting explosives. Evacuate the area to a safe distance and prevent reentry while danger exists. Guard the fire to prevent inadvertent access, exposing anyone to danger.

Insofar as possible, conduct blasting operations between sunup and sundown and during periods of clear visibility. If artificial light is necessary, use approved battery-activated lights. Flashlights shall have nonconductive cases and shall not touch explosives.

Use exploding bridgewire detonators (EBW), or electric blasting caps (EBC), either instant or delay, non-electric system (NONEL), or detcord cap and cord assemblies for exploding charges. Do not use EBC's near powerlines or radio installations in avalanche control work, or near any source of extraneous electricity that may prematurely detonate the EBC.

Never carry primers or loose detonators in pockets or in the same container with dynamite.


Never store or transport detonating cord in the same container with detonators.

Use only explosives or explosive materials approved by Regional Foresters. See *FSM 6761.2* for approval of new explosives.

## 1.2 Inspection

### 1.2.1 Explosive Materials in Storage

Any person storing explosive materials shall inspect the magazine at least every 7 days. This inspection need not be an inventory, but must be sufficient to determine whether there has been unauthorized entry or attempted entry into the magazine. Notify the nearest Regional office of the Bureau of Alcohol, Tobacco and Firearms (BATF), and appropriate State offices within 24 hours of any loss, theft, or unauthorized entry into a magazine (Figure 1-1).

DEPARTMENT OF THE TREASURY — BUREAU OF ALCOHOL, TOBACCO AND FIREARMS			DATE	
REPORT OF THEFT OR LOSS — EXPLOSIVE MATERIALS				
<p><b>Note:</b> Section 842(k), 18 U.S.C. Chapter 40 provides that "It shall be unlawful for any person who has knowledge of the theft or loss of any explosive materials from his stock to fail to report such theft or loss within twenty-four hours of discovery thereof to the Secretary and to appropriate local authorities." Theft or loss must be reported immediately by telephone to the nearest ATF office, listed on reverse, and a report must be made on this form within 24 hours to the same office (27 CFR 181.30). It is suggested that a copy of this report be retained by the person making the report. Attach additional sheets or invoices, if necessary, to provide the required information. Each item should be completed as applicable to the best of your ability.</p>				
1. NAME, ADDRESS AND TELEPHONE NUMBER OF PERSON MAKING REPORT (Include corporate or business name, if applicable)		2. LOCATION OF THEFT OR LOSS (If different from item 1)		
3. THEFT OR LOSS	DATE	TIME	4. ATF OFFICE TO WHICH REPORTED BY TELEPHONE	
a. DISCOVERED				
b. OCCURRED (Show approximate if exact not known)				
c. REPORTED TO ATF BY TELEPHONE				
d. REPORTED TO LOCAL AUTHORITIES			5. NAME AND ADDRESS OF LOCAL AUTHORITY TO WHOM REPORTED	
6. EXPLOSIVE MATERIALS LOST OR STOLEN (Attach invoices or additional sheets, if necessary)				
a. MANUFACTURER OR BRAND NAME (Include date and shift code)		b. QUANTITY (Pounds of Explosives, Number of Caps)	c. TYPE AND DESCRIPTION (Dynamite, Blasting Agents, Detonators, etc. Include for each type, size, MS delay or length of legwire, as applicable)	
				
7. THEFT OR LOSS OCCURRED FROM (Check applicable box)				
<input type="checkbox"/> PERMANENT MAGAZINE	<input type="checkbox"/> PORTABLE MAGAZINE	<input type="checkbox"/> TRUCK	<input type="checkbox"/> WORK SITE	<input type="checkbox"/> OTHER (Explain)
8. ENTRY TO MAGAZINE MADE THROUGH (Complete if applicable)			9. NUMBER AND TYPE OF LOCKS FORCED (Complete if applicable)	
<input type="checkbox"/> DOOR	<input type="checkbox"/> ROOF	<input type="checkbox"/> FLOOR	<input type="checkbox"/> FOUNDATION	
<input type="checkbox"/> WALL	<input type="checkbox"/> CEILING	<input type="checkbox"/> VENTS	<input type="checkbox"/> OTHER (Explain)	
10. OTHER INFORMATION PERTINENT TO THE THEFT OR LOSS				
11. SIGNATURE AND TITLE OF PERSON MAKING REPORT			12. FEDERAL EXPLOSIVES LICENSE OR PERMIT, IF ANY	
FOR ATF USE ONLY				
DATE RECEIVED	TIME RECEIVED	UNIQUE IDENTIFIER		

ATF F 4712 (5400.5) (11-81) PREVIOUS EDITIONS ARE OBSOLETE

Figure 1-1.—Sample theft form.

## ADDRESS AND TELEPHONE LISTING OF ATF OFFICES

Forward completed ATF Form 4712 to the nearest ATF Office listed below (alphabetically by State, Guam, Puerto Rico):

Special Agent in Charge (ATF)  
2121 8th Avenue, North  
Birmingham, Alabama 35203  
Phone: 205-254-1205

Resident Agent in Charge (ATF)  
New Federal Office Bldg.  
U.S. Courthouse, 701 C Street  
Anchorage, Alaska 99513  
Phone: 907-271-5701

Resident Agent in Charge (ATF)  
2721 N. Central Ave.  
Phoenix, Arizona 85004  
Phone: 602-261-2025

Special Agent in Charge (ATF)  
300 N. Los Angeles Street  
(Mailing Address: P.O. Box 1991)  
Los Angeles, California 90063  
Phone: 213-688-4812

Special Agent in Charge (ATF)  
525 Market Street - Room 2540  
San Francisco, California 94105  
Phone: 415-558-6789

Resident Agent in Charge (ATF)  
Room 803  
Federal Bldg.  
Hartford, Connecticut 06103  
Phone: 203-244-2770

Special Agent in Charge (ATF)  
5205 N.W. 84th Ave.  
Miami, Florida 33196  
Phone: 305-350-4368

Special Agent in Charge (ATF)  
C&S Bank Building - Suite 285  
1 West Court Square  
Decatur, Georgia 30030  
Phone: 404-221-6526/27

Resident Agent in Charge (ATF)  
300 Ala Moana Blvd.  
(Mailing Address: P.O. Box 50103)  
Honolulu, Hawaii 96801  
Phone: 808-546-3196

Special Agent in Charge (ATF)  
Suite 300  
2115 Butterfield Road  
Oak Brook, Illinois 60521  
Phone: 313-353-8474

Special Agent in Charge (ATF)  
600 Federal Place  
Louisville, Kentucky 40202  
Phone: 502-582-5211

Special Agent in Charge (ATF)  
Hale Boggs Federal Office Bldg.  
500 Camp Street  
New Orleans, Louisiana 70130  
Phone: 504-682-2350

Special Agent in Charge (ATF)  
John F. Kennedy Bldg.  
(Mailing Address: P.O. Box 9115)  
Boston, Massachusetts 02114  
Phone: 617-223-3818

Special Agent in Charge (ATF)  
Federal Building  
(Mailing Address: P.O. Box 1897)  
Detroit, Michigan 48226  
Phone: 313-226-7300

Special Agent in Charge (ATF)  
U.S. Court House & Fed. Bldg.  
316 North Robert Street  
St. Paul, Minnesota 55101  
Phone: 612-725-7093

Special Agent in Charge (ATF)  
100 West Capital Street  
Jackson, Mississippi 39201  
Phone: 601-490-4205

Special Agent in Charge (ATF)  
1150 Grand Avenue  
Kansas City, Missouri 64106  
Phone: 816-758-7188

Special Agent in Charge (ATF)  
1114 Market Street  
St. Louis, Missouri 63101  
Phone: 314-279-5559

Resident Agent in Charge (ATF)  
2401 Morris Avenue  
(Mailing Address: P.O. Box 327)  
Union, New Jersey 07083  
Phone: 201-341-3184

Special Agent in Charge (ATF)  
90 Church Street  
(Mailing Address: P.O. Box 3842)  
Church Street Station  
New York, New York 10007  
Phone: 212-264-4658

Special Agent in Charge (ATF)  
222 S. Church Street - Suite 404  
Charlotte, North Carolina 28202  
Phone: 704-371-6125

Resident Agent in Charge (ATF)  
U.S. Post Office Building  
Room 315  
Cincinnati, Ohio 4520  
Phone: 513-684-3354

Special Agent in Charge (ATF)  
55 Erie View Plaza - Suite 500  
Cleveland, Ohio 44114  
Phone: 216-522-3374

Resident Agent in Charge (ATF)  
200 N.W. Fifth Street  
Oklahoma City, Oklahoma 73102  
Phone: 405-231-4877

Special Agent in Charge (ATF)  
U.S. Custom House  
2nd and Chestnut Streets  
Philadelphia, Pennsylvania 19106  
Phone: 215-597-7266

Resident Agent in Charge (ATF)  
Federal Building  
1835 Assembly Street  
Columbia, South Carolina 29201  
Phone: 803-677-6723

Special Agent in Charge (ATF)  
4004 Hillboro Road  
Nashville, Tennessee 37215  
Phone: 615-

Special Agent in Charge (ATF)  
1114 Commerce Street  
Dallas, Texas 75242  
Phone: 214-767-2750

Special Agent in Charge (ATF)  
16630 Imperial Valley Dr.  
(Mailing Address: P.O. Box 80927)  
Houston, Texas 77060  
Phone: 713-226-5405

Special Agent in Charge (ATF)  
701 West Broad Street  
Falls Church, Virginia 22046  
Phone: 703-295-2543

Resident Agent in Charge (ATF)  
400 North 8th Street  
(Mailing Address: P.O. Box 10068)  
Richmond, Virginia 23240  
Phone: 804-925-2668

Special Agent in Charge (ATF)  
806 Federal Bldg.  
915 2nd Ave.  
Seattle, Washington 98174  
Phone: 206-442-4485

Special Agent (ATF)  
U.S. Courthouse Federal Bldg.  
Avila Carlos Chardon  
Hato Ray, Puerto Rico 00919  
Phone: 809-753-4084

## PRIVACY ACT INFORMATION

The following information is provided pursuant to section 3 of the Privacy Act of 1974 (5 U.S.C. § 552a)(3).

1. **Authority.** Solicitation of this information is made pursuant to Title XI of the Organized Crime Control Act of 1970 (18 U.S.C. Chapter 40). Disclosure of a theft or loss of explosive materials is mandatory pursuant to 18 U.S.C. § 842(k) for any person who has knowledge of such theft or loss from his stock.
2. **Purpose.** The purpose for the collection of this information is to give ATF notice of the theft or loss of explosive materials, and to furnish ATF with the pertinent facts surrounding such theft or loss. In addition, the information is used to confirm and verify any prior telephonic or other informal notification of a theft or loss of explosive materials.
3. **Routine Use.** The information will be used by ATF to aid in the administration of laws within its jurisdiction concerning the regulation of explosive materials and other related areas. In addition, the information may be disclosed to other Federal, State, foreign, and local law enforcement and regulatory agencies to aid in the enforcement of laws within their jurisdiction.
4. **Effects of not supplying information requested.** 18 U.S.C. § 842(k) makes it unlawful for any person, who has knowledge of the theft or loss of explosive materials from his stock, to fail to report such theft or loss within twenty-four hours of discovery thereof, to the Secretary and to appropriate local authorities. The penalty for violation of this section is a fine of not more than \$1,000 or imprisonment for not more than one year, or both, 18 U.S.C. § 844(b).

## PAPERWORK REDUCTION ACT NOTICE

This request is in accordance with Section 3507, Public Law 96-511, December 11, 1980. The purpose of this information collection is to determine whether the person receiving explosives is eligible to do so under federal law. The information is subject to inspection by ATF officials. This information is mandatory by statute. (18 U.S.C. 842)

ATF F 4712 (5400.5) (11-81)

## 1.2.2 Magazine Condition

Inspect condition of magazine and explosives annually in accordance with the following report format:

### Explosives Storage Magazine Condition Report

Inspector:		Magazine location:	
		Section	Range
		Township	County
National Forest:		Magazine name or number:	
		Date:	
Designated individual responsible for magazine:		Other personnel, if any, designated secondary responsibility:	
Name	Title		
Do these personnel hold current Blaster's Certificate authorizing handling, transportation, and storage? <input type="checkbox"/> Yes <input type="checkbox"/> No			
Is this a Forest Service magazine? <input type="checkbox"/> Yes <input type="checkbox"/> No			

#### I. Magazine Site:

##### A. Conformance with American Table of Distances:

Is maximum storage stenciled or painted on inside wall of magazine? ☐ Yes ☐ No

Maximum quantity of explosives authorized for storage in magazine \_\_\_\_\_ lbs.

Quantity stored \_\_\_\_\_ lbs.

Barricaded? ☐ Yes ☐ No

Distance to nearest inhabited building, dwelling \_\_\_\_\_ feet

Distance to nearest public road \_\_\_\_\_ feet

Distance to nearest ski lift, downhill ski run, or other public facility \_\_\_\_\_ feet

Site *does* ☐ *does not* ☐ conform to standards

##### B. Is there utilization of natural barriers? Describe:

---

---

---

---

---

##### C. Drainage of terrain near magazine, (slope, direction of flow, soil, etc.). Describe:

---

---

---

---

##### D. Exposure to Sun (south slope, north slope, shaded by trees, covered by snowbank, etc.). Describe:

---

---

---

---

##### E. Accessibility to other than authorized personnel, i.e. exposed to careless discharge of firearms, vandalisms, etc. Describe:

---

---

---

---

---

## Explosives Storage Magazine Condition Report continued. . .

**II. Construction of Magazine:****A. Type Structure (check one):**

- ☐ Reinforced concrete    ☐ Brick or masonry  
☐ Frame    ☐ Exposed wood  
☐ Metal-sheathed outside    ☐ Other(Describe): \_\_\_\_\_

Is structure bullet proof? ☐ Yes ☐ No  
 Rodent proof? ☐ Yes ☐ No

**B. Flooring (check one):**

- ☐ Wood—Are nails exposed? ☐ Yes ☐ No  
☐ Earth  
☐ Concrete—Are duckboards, pallets, or rubber mats over concrete? ☐ Yes ☐ No

Are there any spark producing hazards on floor?  
☐ Yes ☐ No

If yes, describe: \_\_\_\_\_  
 \_\_\_\_\_

**C. Ventilation**

Is flooring set back 5 inches from wall? ☐ Yes ☐ No

If concrete floor, are duckboards or pallets provided?  
☐ Yes ☐ No

If yes, how are the vents screened? \_\_\_\_\_  
 \_\_\_\_\_

What is the condition of screening? \_\_\_\_\_  
 \_\_\_\_\_

What type of roof vent is provided? Describe: \_\_\_\_\_  
 \_\_\_\_\_

Are vents installed with an indirect flow of air?  
☐ Yes ☐ No

Is the air venting adequate for this magazine?  
☐ Yes ☐ No

**D. Lightning and Static Protection**

Is there a lightning rod system? ☐ Yes ☐ No

If yes, describe: rod, cables, ground, and condition (corroded? broken?). \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

**III. Method of Storage and Condition of Explosives in Magazine****A. Storage**

Are explosives at least 5 inches from walls?  
☐ Yes ☐ No

Are explosives cases stacked top side up?  
☐ Yes ☐ No

Is there sufficient room between stacks to permit circulation of air? ☐ Yes ☐ No

Are caps or made up primers stored in explosives magazine? ☐ Yes ☐ No

Are explosives stacked so oldest stock may be used first? ☐ Yes ☐ No

Are open or partially used cases, stacked separately from full ones? ☐ Yes ☐ No

Are stacks separated according to type and grade?  
☐ Yes ☐ No

**B. Condition of Explosives**

Are cases damp? ☐ Yes ☐ No

Are explosives damp inside cases? ☐ Yes ☐ No

Are any cases broken, rodent gnawed, or in any way damaged? ☐ Yes ☐ No

*If explosives show signs of deterioration, check appropriate box below:*

Are explosives becoming dark in color?  
☐ Yes ☐ No

Are explosives soft and mushy in texture?  
☐ Yes ☐ No

Are there fumes in magazine? ☐ Yes ☐ No

Is there any indication of leakage in explosives?  
☐ Yes ☐ No

Are cases stained? ☐ Yes ☐ No

If the answer to any of the above is Yes, Describe: \_\_\_\_\_  
 \_\_\_\_\_

Explosives Storage Magazine Condition Report continued. . .

Does any explosive in magazine appear to be deteriorated to the point where it is dangerous to handle and would require disposal by military EOD teams?

☐ Yes ☐ No If yes, describe in full: \_\_\_\_\_

\_\_\_\_\_  
\_\_\_\_\_

**Special Note:**

*If the above described condition exists, close magazine and immediately notify District Ranger, Forest Engineer, Regional Forester, and Regional Blaster Examiner.*

**C. Detonating Cord**

If detonating cord is stored in magazine, is it in moisture and rodent-proof container? ☐ Yes ☐ No

Is it damp, rodent gnawed, or is the protective covering damaged in any way? ☐ Yes ☐ No

If yes, describe: \_\_\_\_\_

\_\_\_\_\_

**D. Detonator (Cap) Magazine**

How far is cap magazine from explosives magazine?  
\_\_\_\_\_ feet

Are caps in rodent proof containers if necessary?

☐ Yes ☐ No

Is magazine rodent proof? ☐ Yes ☐ No

Are caps damp? ☐ Yes ☐ No

Are caps stored in such a manner as to be exposed to any hazard from friction, static, or falling objects?

☐ Yes ☐ No If yes, describe: \_\_\_\_\_

\_\_\_\_\_

Do caps show corrosion, cracking of insulation on leg wires, or other signs of deterioration? ☐ Yes ☐ No

If yes, describe: \_\_\_\_\_

\_\_\_\_\_

Are any other blasting materials other than caps and fuses stored in cap magazine? ☐ Yes ☐ No

If yes, describe: \_\_\_\_\_

\_\_\_\_\_

**IV Cleanliness of Magazine**

Is floor of magazine swept clean? ☐ Yes ☐ No

If no, describe: \_\_\_\_\_

\_\_\_\_\_  
\_\_\_\_\_

Is floor of magazine stained from leaky explosives?

☐ Yes ☐ No

If yes, describe: \_\_\_\_\_

\_\_\_\_\_  
\_\_\_\_\_

Are there any empty explosives containers in magazine?

☐ Yes ☐ No

If yes, describe: \_\_\_\_\_

\_\_\_\_\_  
\_\_\_\_\_

Is general appearance of magazine clean, neat, and orderly?

☐ Yes ☐ No Remarks: \_\_\_\_\_

\_\_\_\_\_  
\_\_\_\_\_

\_\_\_\_\_

**V. Fire Prevention**

Is brush cleared around outside of magazine for at least 50 feet? ☐ Yes ☐ No

How far around magazine is ground cleared to mineral soil?  
\_\_\_\_\_ feet

Are there any serious fire hazards in the immediate vicinity of the magazine? ☐ Yes ☐ No

**VI. Signing and Marking of Magazine**

Does magazine marking conform to Forest Service safety code? ☐ Yes ☐ No If no, describe: \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

## Explosives Storage Magazine Condition Report continued. . .

## VII. Inventory Records

Is an explosives inventory record kept in magazine?

☐ Yes ☐ No

If yes, describe form, or submit copy with inspection report.

---



---



---



---

Where is second copy kept? 

---



---



---



---

Are inventory records (*refer to III D*) neat, clean, legible, and kept up to date? ☐ Yes ☐ No

Is any provision made to date mark cases on arrival at magazine so oldest stock may be identified?

☐ Yes ☐ No If yes, describe: 

---



---



---



---



---



---



---



---



---

## VIII. Miscellaneous

Is magazine securely locked with at least two high security locks? ☐ Yes ☐ No

With special lock meeting BATF regulations?

☐ Yes ☐ NoAre keys strictly controlled? ☐ Yes ☐ NoIs any explosive material not belonging to Forest Service stored in magazine? ☐ Yes ☐ No If yes, describe:

---



---



---

Is anything, particularly iron or spark producing items, other than explosives or caps stored in either explosives or cap magazines? ☐ Yes ☐ No If yes, describe:

---



---



---

## Inspection Rating



Satisfactory



Needs corrections

***Inspector's remarks and recommendations: (If more room is needed, use additional sheet of paper.)***

1.3 Records

Maintain a record of changes in stock inventory and of inspections at each magazine; file a duplicate at a unit headquarters. The record must show the date of inspections and the

inspector's signature, the dates explosives are entered or removed from storage, and the signature or initials of the person entering or removing explosives. The record also must show types of explosives, quantities, and

manufacturer. Figure 1-2a shows a properly filled out form. Figure 1-2b is a blank form that can be duplicated.

Maintain a blasting record, showing the date and time of each blast and the amount and type of explosive used (See Figure 1-3).

Sample

INSPECTION AND INVENTORY RECORD  
(Check Type)  
☒ Explosives Magazine  
☐ Detonator Magazine

Region  
7

Explosive Magazine  
Bentwood

Detonator Magazine  
Bentwood

inspection If stock added or removed, update inventory section		Inventory		Explosives (Type)		Explosives (Type)		Explosives (Type)		Explosives (Type)	
DATE	SIGNATURE	Added Stock	Removed Stock	date	initial	added or removed	quantity	date	initial	added or removed	quantity
7/2	B.C. Jackson	✓		7/14	BCJ	120#	120#	7/16	BCJ	100'	1000'
7/6	B.C. Jackson	✓		7/16	BCJ	4#	116#	7/16	BCJ	100'	900'
7/9	B.C. Jackson	✓		7/17	BCJ	23#	93#	7/17	BCJ	120'	730'
7/13	B.C. Jackson	✓									
7/16	B.C. Jackson	✓									
7/17	B.C. Jackson	✓									
7/20	B.C. Jackson	✓									
7/23	B.C. Jackson	✓									
7/26	B.C. Jackson	✓									
7/30	B.C. Jackson	✓									
8/3	G.G. Jones	✓									

Figure 1-2a.—Example of a properly filled out Inspection and Inventory Record form.

## Inspection and Inventory Record

(Check Type)	Region	Forest & District	Magazine
<input type="checkbox"/> Explosives Magazine			
<input type="checkbox"/> Detonator Magazine			

## Inspection

*If stock added or removed, update inventory section.*

[illegible]

## Inventory

[illegible]

Figure 1-2b.—Blank Inspection and Inventory Record form.

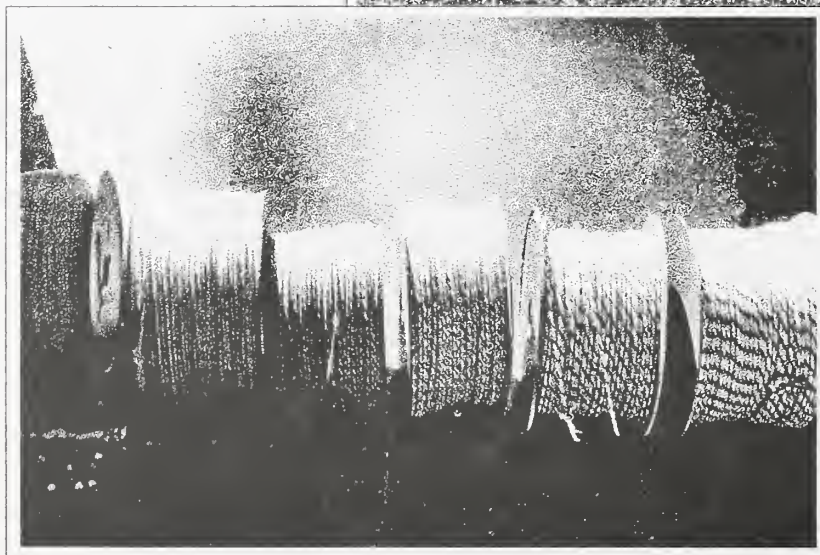
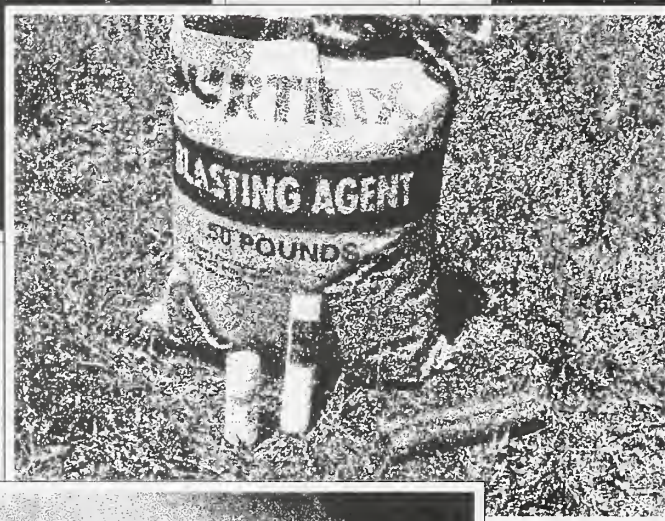
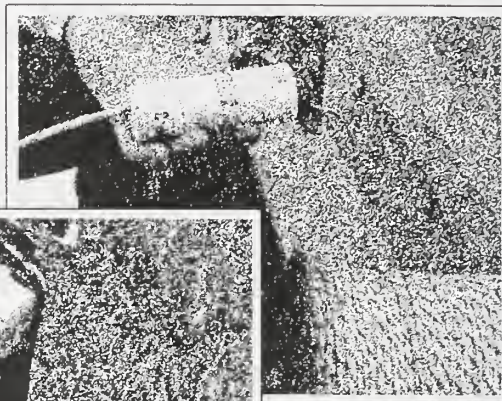
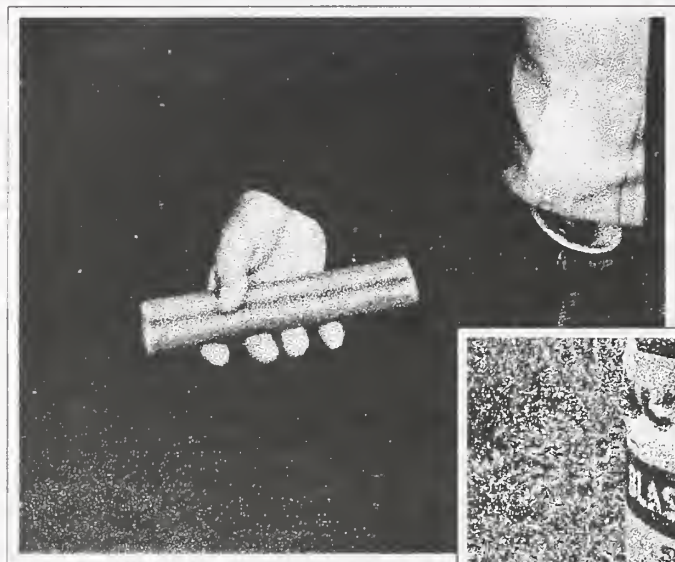
Blast Report			
Date:	Location:	Type Rock:	<div style="text-align: center; border: 1px solid black; padding: 5px; margin-bottom: 10px;"> Sketch of Blast and Delay Electric Blasting Caps  <i>Use North Arrow</i> </div> <div style="border: 1px solid black; height: 300px; width: 100%;"></div>
Sonic Velocity:	Hole Size:	Hole Depth:	
Spacing:	Burden:	Stemming:	
<b>Powder Used</b>			
Brand:	Type:	Sack Size:	Calculated Cu. Yds.:
Powder Factor:	No. Lbs./Hole:	Total Lbs. Used:	
<div style="border-top: 1px solid black; height: 40px; width: 100%;"></div>			Signature
Show all calculations below:			

Figure 1-3.-Blast Report form.

---

Notes:

## Chapter 2



# Chapter 2—Explosives

## Section Contents

<b>2.1 Explosives</b>	<b>13</b>
2.1.1 Explosives	13
2.1.2 Air Gap Sensitivity	14
2.1.3 Cap Sensitivity	14
2.1.4 Strength	14
<b>2.2 Properties Of Explosives</b>	<b>15</b>
2.2.1 Detonation Velocity (VOD)	15
2.2.2 Density	17
2.2.3 Detonation and Borehole Pressure	17
2.2.4 Water Resistance	17
2.2.5 Fume Class	18
2.2.6 Shelf Life	18
2.2.7 Permissibles or Permitted Explosives	18
<b>2.3 Blasting Agents and Ammonium Nitrate</b>	<b>18</b>
2.3.1 Dry Blasting Agents	18
2.3.2 Emulsions	19
2.3.3 Water Gels (Slurries)	20
<b>2.4 Nitroglycerin</b>	<b>22</b>
<b>2.5 Two-Component Cap-Sensitive Explosives</b>	<b>22</b>
<b>2.6 Military Explosives</b>	<b>22</b>
2.6.1 TNT	22
2.6.2 PETN	22
2.6.3 RDX	22
2.6.4 Composition B	22
2.6.5 Pentolite	22

<b>2.7 Initiating Devices</b>	<b>23</b>
2.7.1 Exploding Bridgewire Detonators (EBW)	23
2.7.2 Electric Blasting Caps (EBC)	23
2.7.3 Detonating Cord	24
2.7.4 Nonel® Primadet	25
2.7.5 Primers	25

This chapter classifies commercial blasting compounds according to their explosive class and type. Initiating devices are listed and described. Military explosives are treated separately. The ingredients and more significant properties of each explosive are tabulated and briefly discussed. Data are summarized from various handbooks, textbooks, and manufacturers' technical data sheets.

## 2.1 Explosives

### 2.1.1 Explosives

In general, an explosive has four basic characteristics: (1) it is a chemical compound or mixture ignited by heat, shock, impact, friction, or a combination of these conditions; (2) upon ignition it decomposes rapidly in a detonation; (3) there is a rapid release of heat and large quantities of high-pressure gasses that expand rapidly with sufficient force to overcome confining forces; and (4) the energy released by the detonation of explosives produces four basic

effects: (a) rock, fragmentation; (b) rock displacement; (c) ground vibration; and (d) airblast.

The ingredients used in the manufacture of explosives are classified as:

**Explosives bases.** An explosive base is a solid or a liquid which, upon application of heat or shock, breaks down very rapidly into gaseous products, with an accompanying release of heat energy. Nitroglycerine is an example.

**Combustibles.** A combustible combines with excess oxygen in an explosive to achieve oxygen balance, to prevent the formation of nitrous oxides (toxic fumes) and to lower the heat of the explosion.

**Oxygen carriers.** Oxygen carriers assure complete oxidation of the carbon in the explosive mixture, which inhibits the formation of carbon monoxide. The oxygen carriers assist in preventing a lowering of the explosion temperature. A lower heat of explosion means a lower energy output and thereby less efficient blasting.

**Antacids.** Antacids are added to an explosive compound to increase its long term storage life, and to reduce the acidic value of the explosive base, particularly nitroglycerin (NG).

**Absorbents.** Absorbents are used in dynamite to hold the explosive base from exudation, seepage, and settlement to the bottom of the cartridge or container. Sawdust is often used as an absorbent.

**Anti-freeze.** Anti-freeze is used to lower the freezing point of the explosive.

### 2.1.2 Air Gap Sensitivity

Air gap sensitivity is a measure of an explosive's cartridge-to-cartridge sensitivity to detonation, under test conditions, expressed as the distance through air at which a primed half-cartridge (donor) will reliably detonate an un-primed half-cartridge (receptor).

### 2.1.3 Cap Sensitivity

Cap sensitivity is a measure of the minimum energy, pressure, or power required for initiation of a detonation; i.e., "cannot be detonated by means of a No. 8 test blasting cap when unconfined."

### 2.1.4 Strength

Strength is usually considered to be the ability of an explosive to do useful work. This term was erroneously associated with case strength markings. Neither weight strength nor bulk strength is a good basis on which to choose an explosive but, because many blasters still use the term, a history of the term is included here.

The word "straight" was first applied to dynamites when dynamite was a mixture of nitroglycerin and an inert filler, such as kieselguhr (diatomaceous earth).

A 60-percent dynamite contained 60 percent nitroglycerin by weight and was three times as strong as a 20-percent dynamite. Present dynamites, however, substitute active ingredients, such as sodium nitrate and carbonaceous fuel for the inert filler. This adds substantially to the energy in the

explosive. Consequently, a 60-percent straight dynamite, which contains 60 percent nitroglycerin by weight, is only about 1-1/2 times as strong as a 20-percent dynamite, not three times as strong. This is because of the additional energy supplied by the sodium nitrate and carbonaceous material in the 20-percent grade.

Two strength ratings are used for commercial dynamite. **Weight strength** compares explosives on a weight basis and **cartridge strength** or **bulk strength** compares explosives on a volume basis.

Strengths are expressed as a percentage, with straight nitroglycerine dynamite taken as the standard for both weight and

cartridge strength ratings. For example, according to the strength rating system, 1 pound of extra dynamite with a 40-percent weight strength and 1 pound of ammonia gelatin with a 40-percent weight strength are each said to be equivalent to 1 pound of 40-percent straight dynamite. A 1-1/4 by 8-inch cartridge (Figure 2-1) of extra dynamite with a 30-percent cartridge strength and a 1-1/4 by 8-inch cartridge of semigelatin with a 30-percent cartridge strength rating are each said to be equivalent to a 1-1/4 by 8-inch cartridge of 30-percent straight dynamite. By definition, the weight strength and cartridge strength of an explosive are said to be equal when the specific gravity of the explosive is 1.4, the density of most straight dynamites.

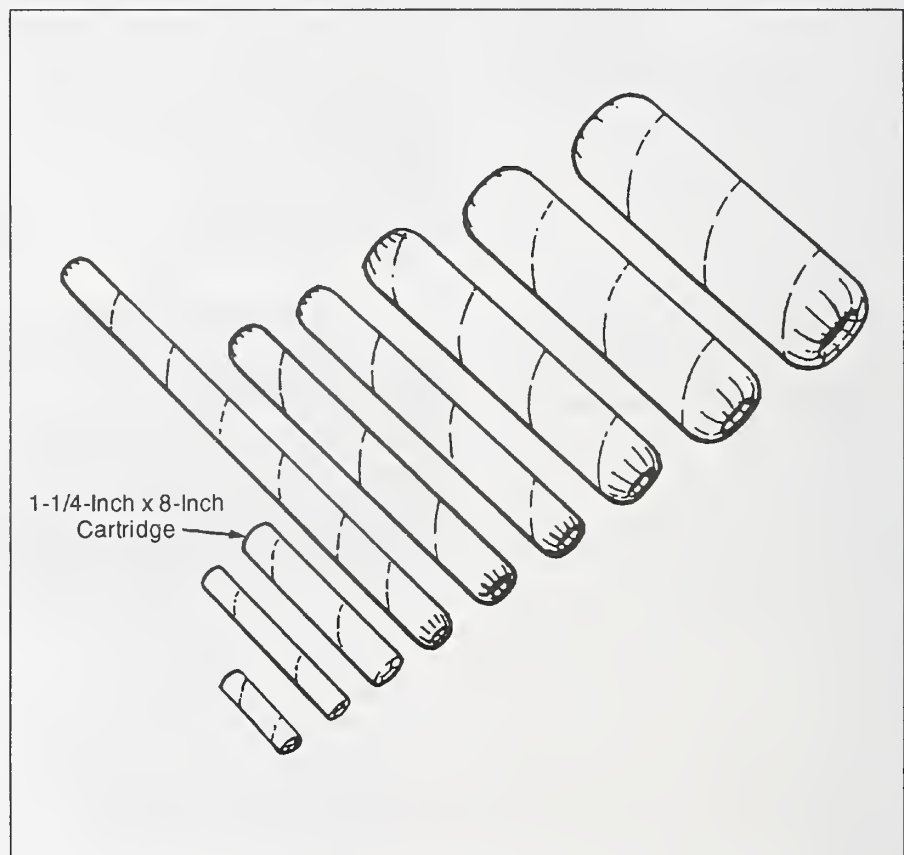


Figure 2-1.—Standard cartridge sizes.

To add further to the confusion, a 50-percent straight dynamite and a 50-percent extra dynamite produce different results in the field, primarily because of a difference in density and detonation velocity. The relation between the weight strength and cartridge strength of a given explosive depends on its density. When the specific gravity and weight and cartridge strength of 50-percent straight NG dynamite (1.4 and 17,000 fps) and 50-percent low-density ammonia dynamite, low velocity series (1.2 and 8,100 fps) (Tables 2-1, 2-2, and 2-3) are said to be equal or do the same work, it becomes clear that neither weight strength nor cartridge strength is a good basis on which to choose an explosive. Detonation pressure, a function of detonation velocity and density, is a better indicator of an explosive's ability to perform work.

## 2.2 Properties Of Explosives

By knowing what properties are critical to performance, meaningful predictions can be made in blast design. These properties are: detonation velocity, density, detonation pressure, water resistance, and fume class. For a given explosive these properties vary with the manufacturer and their methods of property measurement (Tables 2-1 – 2-6). Shelf life for all nitroglycerin products is 1 year.

### 2.2.1 Detonation Velocity (VOD)

Detonation velocity is an important property to consider when rating an explosive. It may be expressed

Table 2-1.—*Properties of straight nitroglycerin dynamite.*

Weight strength (percent)	Cartridge strength (percent)	Density	Confined velocity (VOD)(fps)	Water resistance	Fume class <sup>*</sup>	Cartridge count
60	60	1.3	19,000	Good	Poor	106
50	50	1.4	17,000	Fair	Poor	104
40	40	1.4	14,000	Fair	Poor	100
30	30	1.4	11,500	Poor	Poor	100
20	20	1.4	9,000	Poor	Poor	100

<sup>\*</sup> See Section 2.2.5, pg. 18.

Table 2-2.—*Properties of high-density ammonia dynamite.*

Weight strength (percent)	Cartridge strength (percent)	Density	Confined velocity (VOD)(fps)	Water resistance	Fume class <sup>*</sup>	Cartridge count
60	52	1.3	12,500	Fair	Good	110
50	45	1.3	11,500	Fair	Good	110
40	35	1.3	10,500	Fair	Good	110
30	25	1.3	9,000	Fair	Good	110
20	15	1.3	8,000	Fair	Good	110

<sup>\*</sup> See Section 2.2.5, pg. 18.

Table 2-3.—*Properties of low-density ammonia dynamite, low-velocity series.*

Weight strength (percent)	Cartridge strength (percent)	Density	Confined velocity (VOD)(fps)	Water resistance	Fume class <sup>*</sup>	Cartridge count
65	50	1.2	8,100	Fair	Fair	120
65	45	1.1	7,800	Poor	Fair	129
65	40	1.0	7,500	Poor	Fair	135
65	35	1.0	7,200	Poor	Fair	141
65	30	.9	6,900	Poor	Fair	153
65	25	.9	6,500	Poor	Fair	163
65	20	.8	6,300	Poor	Fair	174

<sup>\*</sup> See Section 2.2.5, pg. 18.

Table 2-4—Confined detonation velocity and borehole loading density of ANFO.<sup>1</sup>

Borehole diameter (inches)	Confined velocity (fps)	Loading density (lb/ft of borehole)
2	5,000 - 7,500	1.1 - 1.3
3	9,000 - 10,000	2.5 - 3.0
4	10,500 - 11,500	4.4 - 5.2
5	11,500 - 12,500	6.9 - 8.2
6	12,000 - 12,800	9.9 - 11.7
7	12,300 - 13,100	13.3 - 15.8
8	12,500 - 13,300	17.6 - 20.8
9	12,800 - 13,500	22.0 - 26.8
10	13,000 - 13,500	27.2 - 32.6
11	13,200 - 13,500	33.0 - 39.4
12	13,300 - 13,500	39.6 - 46.8

<sup>1</sup> Density: .85-.95 g/cc.

Water resistance: Packaging only; do not use under wet conditions.

Shelf life: 1 year (fuel oil begins to separate after 6 months and will stain bags.)

Table 2-5.—Properties of emulsions.

Product	Density g/cc	Velocity ft/sec	Water Resistance	Fume Class*	Shelf Life
Emulex 510	1.15	16,300	Excellent	1	No change after 1 year
Emulex 520	1.16	15,200	"	1	"
Emulex 710	1.19	18,000	"	1	"
Emulex 730	1.21	17,000	"	1	"
Emulex 750	1.35	19,000	"	1	"

\* See Section 2.2.5, pg. 18.

Table 2-6.—Properties of water gels.

Product	Density g/cc	Velocity ft/sec	Water Resistance	Fume Class*	Shelf Life
Tovex 90	0.90	14,100	Good	1	1 year
Tovex 100	1.10	14,860	Excellent	1	"
Tovex 300	1.02	11,500	Good	A	"
Tovex 650	1.35	14,750	Excellent	1	"
Tovex 800	1.20	15,750	Excellent	1	"
Tovex T-1	0.25 lb/ft	22,000	Good	3	"

\* See Section 2.2.5, pg. 18.

as a confined or unconfined value and is normally given in feet per second (fps). The confined detonation velocity measures the speed at which the detonation wave travels through a column of explosive within a borehole or other confined space. The unconfined velocity indicates this rate when the explosive is detonated in the open. Because explosives generally are used under some degree of confinement, the confined value is the more significant. Most manufacturers, however, measure detonation velocity in an unconfined column of explosive 1-1/4 inches in diameter, although some measurements are made within the confinement of an iron pipe or using a different diameter. If unconfined velocities are all that are available, add 20 percent to 25 percent to these figures to get confined velocities.

The confined detonation velocity of commercial explosives varies from 5,000 to 25,000 fps (Tables 2-1 – 2-6). With cartridge explosives, the confined velocity is seldom attained because complete confinement is usually impossible. For blasting in hard rock, a high-velocity explosive is preferable (straight dynamite). In a softer or highly jointed rock, a low-velocity explosive (ANFO) with a heaving action may give satisfactory results at a lower cost. Some explosives, and particularly blasting agents, are more sensitive to diameter changes than others. In charges with larger diameters, say 6 inches or more, the velocity may be medium to high. But as diameters get smaller, the velocity is reduced until, at the blasting agent's critical diameter, approximately 2 inches, propagation is no longer assured and misfires are likely.

## 2.2.2 Density

The density of an explosive may be expressed in terms of specific gravity. Specific gravity is the ratio of the density of the explosive to the density of water under standard conditions. The specific gravity of commercial explosives ranges from 0.6 to 1.7 g/cc. For free-running explosives, the density is often specified as the pounds of explosive per foot of charge length in a given size borehole. With few exceptions, denser explosives give higher detonation velocities and pressures.

Density is an important consideration when choosing an explosive. For difficult blasting conditions or where fine fragmentation is required, a dense explosive is necessary. In easily fragmented rock or where fine fragmentation is not needed, a low-density explosive will often suffice. Low-density explosives are particularly useful in the production of riprap or other coarse products.

The density of an explosive is also important when working under wet conditions. An explosive with a specific gravity of less than 1.0 will not sink in water.

## 2.2.3 Detonation and Borehole Pressure

Detonation pressure is a function of the detonation velocity and density of an explosive. The nomograph (Figure 2-2) can be used to approximate the detonation pressure of an explosive when the detonation velocity and specific gravity are known. As can be seen, the

detonation pressure is more dependent on detonation velocity than specific gravity. A high detonation pressure is necessary when blasting hard, dense rock. In softer rock, a lower pressure is sufficient. Detonation pressures of explosives range from 10 to over 140 Kilobars. (1 Kilobar = 14,504 psi).

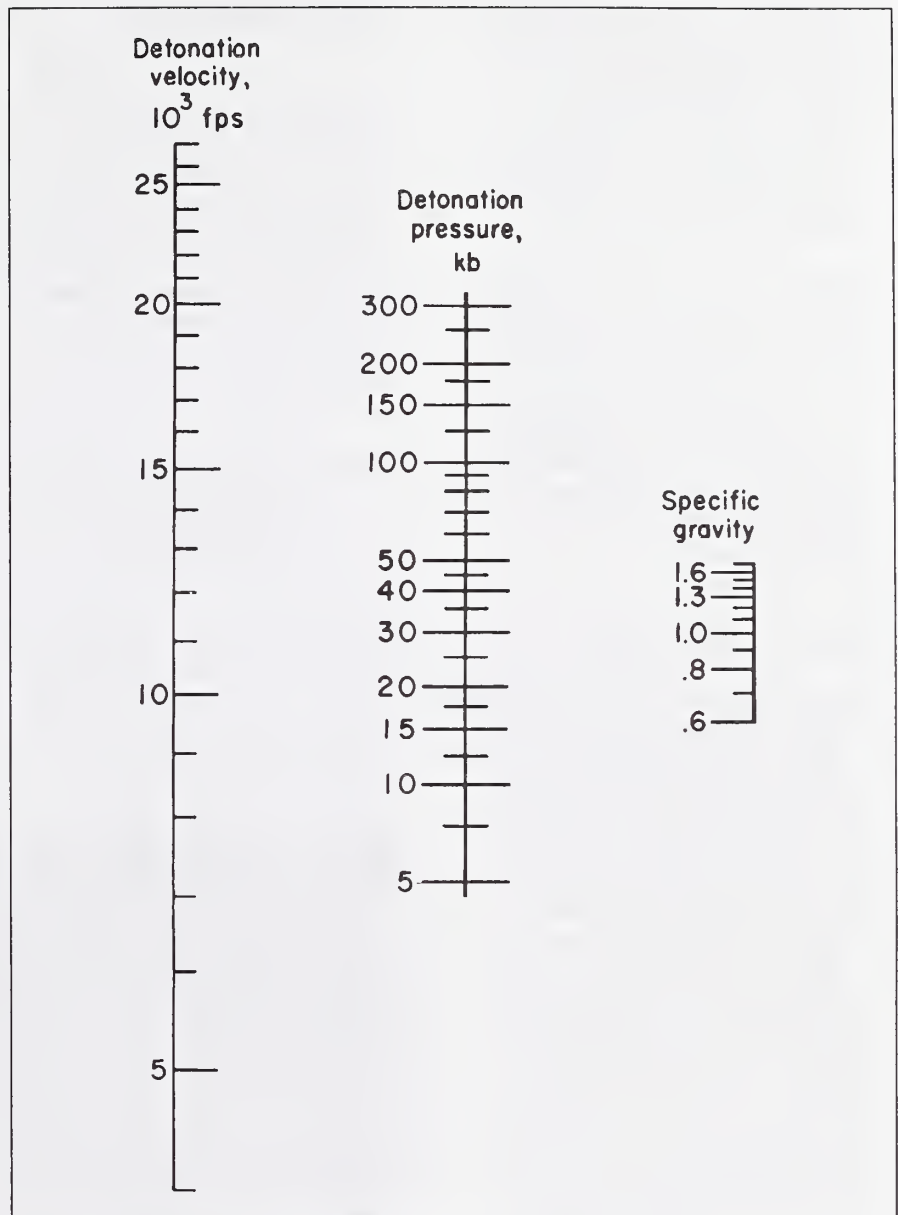


Figure 2-2.—Nomograph for finding detonation pressure.

## 2.2.4 Water Resistance

An explosive's water resistance is a measure of its ability to withstand exposure to water without deteriorating or losing sensitivity. Sensitivity is the ease with which an explosive detonates. In dry work, water resistance is of no consequence. If water is standing in the borehole, and the

time between loading and firing is fairly short, an explosive with a water-resistance rating of "good" is sufficient. If the exposure is prolonged, or if the water is percolating through the borehole, "very good" to "excellent" water resistance is required.

In general, gelatins and emulsions offer the best water resistance. Higher-density explosives have fair to excellent water resistance, whereas low-density explosives and blasting agents have little or none. Brown nitrogen oxide fumes from a blast often mean the explosive has deteriorated from exposure to water.

## 2.2.5 Fume Class

Ideally, detonation of a commercial explosive produces water vapor, carbon dioxide, and nitrogen. In addition, undesirable poisonous gases such as carbon monoxide and nitrogen oxides are usually formed. These gases are known as fumes, and the fume class of an explosive indicates the nature and quality of the undesirable gases formed during detonation. Better ratings are given to explosives producing smaller amounts of fumes. For open work, fumes are not usually an important factor. In confined spaces, however, the fume rating of an explosive is important. In any case, the blaster should insure that everyone stays away from fumes generated in a shot.

Fume classes can be from poor to good for dynamites and are rated Class A or B by the Bureau of Mines and Class 1, 2, or 3 by IME. Class A and Class 1 typically emit less noxious fumes per gram of explosive than Class B or Classes 2 or 3.

## 2.2.6 Shelf Life

Shelf lives of the various products described are listed in their respective tables. For most explosives products a shelf life of 1 year is recommended, although satisfactory performance can be expected from some products 2, 3, and even 4 years later. Consult appropriate manufacturer to determine shelf life ratings beyond 1 year.

## 2.2.7 Permissibles or Permitted Explosives

A permissible explosive is one which has been approved by the U.S. Bureau of Mines or the British Ministry of Fuel and Power for use in gas or dust-filled mines. When detonated or exploded, all explosives produce a flame that varies in volume, duration, and temperature. Black powder produces the longest lasting flame, while dynamites typically produce a shorter lasting, but more intense flame. Permissible explosives are especially designed to produce a flame of low volume, short duration, and low temperature. This is accomplished by adding certain salts to the explosive formula in order to cool or quench the flame to prevent the ignition of gas or dust within the confined space of a mine.

Permissible explosives are generally modified types of gelatin or ammonia dynamites. They are similar in packaging and appearance to other dynamites.

## 2.3 Blasting Agents and Ammonium Nitrate

A blasting agent is any material or mixture consisting of a fuel and oxidizer that is intended for blasting and that is not otherwise classified as an explosive.

A blasting agent consists primarily of inorganic nitrates and carbonaceous fuels (ammonium nitrate). The addition of an explosive ingredient, such as TNT changes the classification of the mixture from a blasting agent to an explosive.

When unconfined, blasting agents cannot be detonated by means of a No. 8 test blasting cap unless an explosive ingredient or sensitizer is added. Number 8 test caps contain the equivalent of 2 grams of a mixture of 80 percent mercury fulminate and 20 percent potassium chlorate. Nitrocarbonitrate is synonymous with a blasting agent and is an official classification for interstate transportation.

Blasting agents may be classified as (1) dry blasting agents, (2) emulsions, or (3) water gel (slurry) blasting agents.

### 2.3.1 Dry Blasting Agents

Although dry blasting agents were patented in Sweden in 1867 and were commercially developed in this country as a canned product in 1935, it was not until the mid-1950's with the development of ANFO (ammonium nitrate fuel oil) that their full potential was realized. At that time dynamite had about 85 percent of the explosives market. By 1989 dynamites had dropped to 3 percent of the market.

Dry blasting agents are basically a mixture of granular or prilled ammonium nitrate and a fuel such as fuel oil or other carbonaceous material.

Dry blasting agents are not cap-sensitive and must be initiated by a high-explosive primer or booster (Figure 2-3). To ensure efficient detonation of a blasting agent, it is important that a high-velocity primer booster equal to the borehole diameter be used. Inadequate priming imparts a low initial detonation velocity to a blasting agent and in extreme cases the reaction will die out, which causes a deflagration.

In charge diameters of 6 to 15 inches, dry blasting agents attain confined detonation velocities of 12,000 to 15,000 fps. But in diameters near 2 inches, the velocity is reduced to about 6,000

fps and deflagration rather than detonation occurs.

Advantages of these insensitive dry blasting agents are their safety in transportation, storage, and handling, as well as their ease of loading and their low price when compared to other explosives. In their free-flowing form, they have a great advantage over cartridge explosives, because they completely fill the borehole. This direct coupling to the walls of the borehole ensures a more efficient use of explosive energy than can be obtained with cartridge explosives, which usually cannot be completely coupled.

The most widely used dry blasting agent is a mixture of ammonium nitrate prills and fuel oil, commonly referred to as ANFO. Theoretically, the percentage of ingredients by weight, in oxygen-

balanced ANFO is 94.5 percent ammonium nitrate and 5.5 percent fuel oil. In actual practice the proportions are 94 percent and 6 percent. The extra fuel oil is added so that a sufficient amount is intimately combined with the ammonium nitrate to ensure an efficient chemical reaction.

Although the specific gravity of dry blasting agents varies from 0.5 to greater than 1.0, the specific gravity of common ANFO varies from 0.80 to 0.85. Table 2-4 on page 16 shows how the confined detonation velocity and the loading density of an ANFO mixture vary with borehole diameter. The range of values covers the most common varieties of ANFO when poured into the borehole. Pneumatic loading results in higher detonation velocities and higher loading densities, particularly in smaller holes. The confined velocities also assume that a primer of sufficient size and velocity is used. The figures are averages of manufacturers' specifications.

ANFO's greatest disadvantage is that it is extremely hygroscopic (absorbs water easily) and should not be used under wet conditions because it may misfire.

### 2.3.2 Emulsions

Although relatively new to the explosive industry, emulsion research and development began in the early 1960's with parallel research and development being done on both emulsions and slurries by many explosive manufacturers.

Emulsion explosives were first commercialized in the mid-1970's in the form of blasting agents. These initial products used entrapped air, achieved by



Figure 2-3.—Booster with detonator cord.

gassing, which severely limited their widespread use. About 1980, the use of glass microballoons for sensitivity led to the commercialization of cap-sensitive emulsions and vastly improved blasting agent emulsions. Further development has led to commercial permissible and seismic cap-sensitive emulsions as well as emulsion/ANFO blends.

The basic chemistry is the combination of an oxidizer with the fuel that will maintain a detonation reaction. The traditional nitrate salts continue to supply the oxidizer requirements while the fuel components continue to be mineral or organic carbon compounds.

Emulsions are the first commercial explosive manufactured with all liquid oxidizers and liquid fuels. The liquid oxidizers are dispersed as microscopic droplets in the liquid fuel. The result is a very intimate mixture of these components, leading to a vastly improved intimate reaction zone, hence a more complete and efficient reaction.

The emulsions manufactured are water-in-oil emulsions. The nitrate salt solution and water (oxidizer) are refined into a mixture of oils and waxes (fuels). After appropriate confinement the minute oxidizer droplets are tightly oriented in the continuous phase of the fuels. The emulsifying agent in the fuel mixture stabilizes the emulsion, thus eliminating the ability of the oxidizer droplets to break the fuels grasp and coalesce and separate out.

With most emulsion formulations there is very little change in their viscosity at ambient temperatures down to 10°F. They do begin to get thinner when temperatures exceed 100°F.

The shelf life and stability of emulsion explosives are excellent with no change in their explosive properties after 1 year.

Emulsions do not utilize explosive sensitizers, and do not become an explosive until after the addition of the microballoons or air voids. For this reason emulsions are perhaps the safest explosive, other than ANFO, in terms of flame, impact, and friction resistance.

Independent studies done to determine at what severe conditions emulsions will detonate, clearly show emulsions have a higher degree of resistance to detonation from standard impact and friction tests than either slurries or dynamites.

However, emulsions are explosives and as such are designed to detonate. The relatively safe emulsions demand respect and the proper handling requirements afforded to all explosives.

The extremely refined mixture of oxidizers and fuels in an emulsion results in a near molecular explosive, which dictates very high detonation velocity (VOD) (VOD as high as 19,000 ft/sec).

The oily surface of emulsions provides excellent water resistance. Emulsion explosives do not rely on packaging for any degree of water protection.

The type and quantity of air voids used to sensitize an emulsion dictates its degree of sensitivity. The sensitivity of today's typical emulsion ranges from a high explosive sensitive to a No. 8 test cap at 10°F to insensitive blasting agents that require a high explosive booster for initiation. (See page 16, Table 2-5 for further properties.)

### 2.3.3 Water Gels (Slurries)

Water gel explosives consist of oxidizing salts, fuels, and sensitizers dissolved or dispersed in a continuous liquid phase. The entire system is thickened and made water-resistant by the addition of gells and cross-linking agents. The oxidizing salts are usually selected from ammonium nitrate, or calcium nitrate. Aluminum, Gilsonite, and oil are frequently used as fuels. Sensitization may be provided by chemical sensitizers such as the nitrate salts of organic amines, nitrate esters of alcohols, perchlorate salts, or small particles of aluminium. Physical sensitization may be provided by entrapped air bubbles either alone or in combination with chemical sensitizers.

As far back as 1958, duPont manufactured water gels under the brand name of "Tovex" for use in large diameter boreholes. But, it was not until the 1960's that a sensitizer called monomethylamine nitrate was developed that could reliably provide consistent detonation in holes as small as 1 inch in diameter.

In 1989 duPont sold their explosives interest to Explosives Technologies International (E.T.I.), 2700 Youngfield St. Suite 251, Lakewood, CO 80215.

E.T.I. subjected its new product to a series of tests far tougher than any used before. The tests cited were made only to compare the action of "Tovex" and dynamite when subjected to similar test conditions. Tests were conducted using grades of "Tovex" that are sensitive to initiation by a standard No. 6 electric blasting cap. In addition, "Detraprime," the

companion primer for non-cap-sensitive grades of "Tovex" was subjected to the same tests.

In the standard E.T.I. drop test, most dynamites detonate under an impact of a 4.4 pound weight dropped from a height of 15 inches. In the same type of test, Tovex has not initiated under the impact of an 11 pound weight at the maximum drop of 52 inches.

In the bullet test Tovex was placed against a metal plate and a 150-grain, .30-'06 bullet was fired at a velocity of 2,625 feet-per-second into it from a range of 75 feet. The Tovex shattered, but did not detonate.

These tests are not meant to imply that Tovex cannot be detonated under more severe conditions. Users should recognize that Tovex water gels and Detaprime primers are explosives and should be treated as such. While this specific test indicates the relative safety characteristics of Tovex as well as other water gels, it does not mean that this product cannot be detonated under other conditions or by more severe shocks, such as higher velocity bullets.

Fire is another source of accidental detonation of explosives during transportation and storage. When subjected to an open flame, Tovex will burn. However, in a test conducted by the Canadian Government, an enclosed truck containing 5 tons of Tovex did not detonate when burned.

Ideally, an explosive material is sensitive to primer initiation and insensitive to accidental initiation. One of the advantages of water gels is that they are reliably sensitive to conventional priming methods, yet significantly more resistant than dynamite to

accidental initiation from abusive impact, shock, or fire. Tovex water gels include both cap-sensitive and non-cap-sensitive products. Even the most sensitive Tovex grades have made most standard safety tests obsolete because they fail to detonate at the upper limits of these tests.

In addition to improved safety, some important properties of water gel explosives include density, velocity, sensitivity, and water resistance. As with any explosive, a single factor does not indicate the suitability of a product for any given application. All the physical properties must be considered as an intrinsic unit with each physical property being considered in relation to the other. Neither density nor velocity as individual properties determines the utility of an explosive. When considered together they can be used to determine an approximate value for the detonation pressure and as such become a useful tool in determining which water gel will produce the desired results economically.

Water gel densities range from about .80 g/cc to 1.60 g/cc, with most gels having a density between 1.0 g/cc and 1.35 g/cc. Because water gels tamp more readily in small-diameter holes and slump in larger diameter holes, water gel explosives can be loaded at higher borehole density than normally obtained with the most dense dynamites. For example, a 1-1/4-inch diameter water gel at a 1.15-g/cc density string loads in a 1-3/4-inch borehole at about 0.60 lb/ft. It can be easily tamped to a borehole density of over 1 lb/ft.

With this greater control of borehole density, blasters can increase the load to pull a tough toe in quarry blasting or extend

drill patterns. When the cartridge is loaded without slitting, the same water gel package is rigid enough to support a column load.

The detonation velocity of most water gels increases as their diameter and degree of confinement increase. In actual field use, the detonation velocity of the water gel may be greater or less than the published velocity, depending on borehole diameter and confinement.

The sensitivity of water gels to initiation is affected by product temperature. In general, higher product temperatures increase sensitivity while lower product temperatures decrease sensitivity. Thus, changes in primer size or energy may be required depending on the product temperature at the time of initiation. The product temperature should be measured if there is any question about priming requirements. Blasters using Tovex water gels should use a booster as a primer at 30°F or less.

It should be emphasized that the temperature of the product when it is being loaded will not remain the same, but will equalize in time to the temperature of the borehole. While freezing does not reduce the effectiveness or safety advantages of Tovex water gels, a cold product must be allowed to reach minimum priming temperature before initiation is attempted without a booster.

The water resistance of water gels is generally excellent, but can be significantly decreased if the product is not used in a proper manner. As packaged, their water resistance classification is excellent. (For other properties see Page 16 Table 2-6).

## 2.4 Nitroglycerin

Nitroglycerin based products are being phased out and other safer products are being used as substitutes.

## 2.5 Two-Component Cap-Sensitive Explosives

Two-component cap-sensitive explosives consist of ammonium nitrate prills or cast sticks and liquid nitromethane that, when properly mixed, become cap-sensitive. They offer an advantage in storage and transportation because they are not classified as an explosive until mixed. These components become class A explosives when mixed and must be stored and transported as such after mixing (See Table 2-7).

## 2.6 Military Explosives

Several compounds and mixtures originally developed for military purposes have commercial applications. Only those with significant industrial application are discussed.

### 2.6.1 TNT

TNT (trinitrotoluene) was used commercially as early as 1891. It is a stable, cap-sensitive compound, with good water resistance. Cast TNT has a density of 1.56 g/cc and a confined detonation velocity of about

Table 2-7.—Properties of two component explosives.

Product	Density g/cc	Velocity ft/sec	Water Resistance	Fume Class	Shelf Life
Thermex Y	1.22	20,000	Package only	1	1
Kinestick	1.1	18,000	Package only	1	1

22,000 fps, and is used as a primer and booster for blasting agents.

TNT may be used as a sensitizer for slurries. Several explosive mixtures, such as pentolite and composition B are formulated with TNT as an ingredient.

### 2.6.2 PETN

PETN (pentaerythritol tetranitrate) has a crystal density of 1.76 g/cc and a confined detonation velocity of over 25,000 fps.

In various degrees of granulation, it is used as a priming composition in detonators, a base charge in blasting caps, a core load for detonating cord, and in the manufacture of pentolite. The use of PETN in detonating cord is discussed under section 2.7.3, page 24. PETN is a secondary explosive and as such is not as sensitive as primary explosives such as lead azide or nitro. Cast primers of PETN are also supplied as shape charges.

### 2.6.3 RDX

RDX (cyclotrimethylene-trinitramine) is second in strength to nitroglycerin among common

explosive substances. When compressed to a density of 1.70, it has a confined detonation velocity of 27,000 fps.

RDX is the primary ingredient in composition B. Their plasticity and high detonation velocity make them ideal as shaped charges for oil well perforators (jet perforators) and furnace papers (jet tappers). RDX is often times the base charge for detonators.

### 2.6.4 Composition B

Composition B is a mixture of RDX and TNT with 1 to 4 percent wax added. When cast, it has a density of 1.65 and a detonation velocity of about 25,000 fps. Like pentolite, composition B is used in the cast form as a primer and booster for blasting agents.

### 2.6.5 Pentolite

Pentolite is a mixture of PETN and TNT. The percentage of PETN can be from 20 percent to 50 percent, with the remainder being TNT. It was originally used for burster charges in military explosive devices and is now used for commercial boosters.

## 2.7 Initiating Devices

### 2.7.1 Exploding Bridgewire Detonators (EBW)

The inert components of an exploding bridgewire detonators (EBW) are similar to standard electric blasting caps (EBC) (Figure 2-4). The major difference is that EBW's contain no primary explosives. A fine gold bridgewire is in contact with PETN, a secondary explosive.

To function properly, a very large electric current must be delivered to the bridgewire in a very short period of time. This heats the wire through the vaporization phase so rapidly that the wire explodes with enough force to detonate the secondary explosive. If either the amount of current or the rate of application is incorrect, the EBW will not function properly. It may deflagrate, but will not detonate. This means that most sources of extraneous electricity that may detonate an EBC are not a hazard when using an EBW (Table 2-8). Static electricity, radio transmissions, automotive batteries or ignition system, chain saw magnetos, or most generator-type blasting machines will not detonate an EBW. A special field-firing set capable of generating a timed 3,000 volts is required. A special model suitable for seismic work is also available.

An EBW can be inserted directly into explosives or can be used to initiate detonating cord, similar to an EBC. A maximum of six detonators can be fired simultaneously in series, but

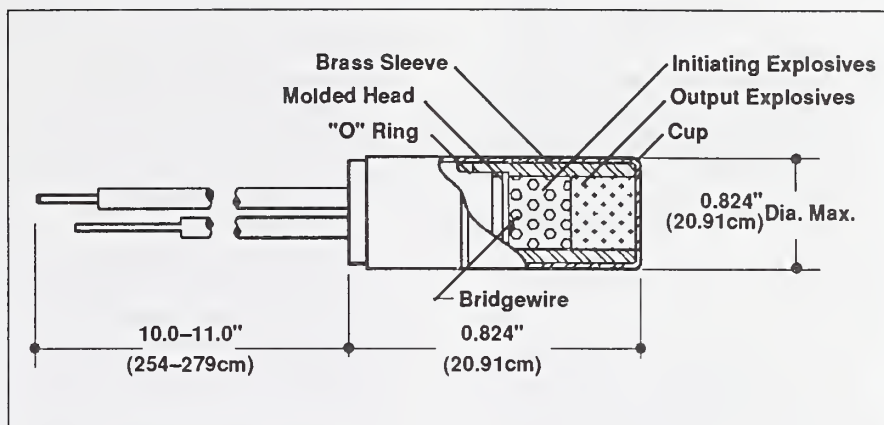


Figure 2-4.—EBW Detonator RP-80.

Table 2-8.—Electric Detonators Hot-wire vs. EBW

Current	Hot-wire	EBW
Threshold	1.0 amp	200 amp
Operating	5.0 amp	>450 amps
Voltage		
Threshold	<20 volt	500 volt
Operating	20 volt	3000 volt
Energy		
Threshold	0.2 joule	0.2 joule
Power		
Threshold	1 watt	100,000 watt
Function Time		
Typical	1 millisec	1 microsec

because tolerances can vary among EBW's, consult the manufacturer before firing more than two in series.

Because an EBW contains only secondary explosives (PETN), delay detonators are not available. EBW's are recommended for situations where static or other extraneous electricity is a problem, or where fire or impact are factors to be considered, and where unit cost is not extremely important. (See Chapter 6.2 *Fireline Explosives*).

### 2.7.2 Electric Blasting Caps (EBC)

The electric blasting cap is the most commonly used device for initiating high explosives. The cap may be inserted directly into the explosive cartridge or used in conjunction with detonating cord. An electric blasting cap consists of two insulated leg wires inserted in an insulated metal capsule and connected by a thin-filament bridgewire. When enough current is applied to the leg wires, the bridgewire gives off heat energy and ignites a flash charge of heat-sensitive explosive, usually

lead azide. The explosion of the flash charge detonates a primer charge, which in turn detonates a base charge of powerful explosive such as PETN or RDX. In some cases the flash and primer charges are combined. The base charge of the cap detonates with sufficient force to initiate a cap-sensitive explosive or detonating cord.

The advantages of electric blasting caps over cap-and-fuse include safety in handling, variety of delay periods, and the ability of the blaster to choose the exact time of detonation. When working in populated areas, noise and resulting public relations problems are reduced by initiating the charge in the borehole with delay blasting caps instead of using trunklines and downlines of detonating cord.

When using electric blasting caps, avoid stray electric currents, such as those caused by power cables lying on the ground, particularly when the ground is wet. Lightning is another source of possible premature detonation. Radio frequency energy is a potential hazard, although the possibility of a premature explosion due to this source is extremely remote.

Consult manufacturer's data for electric current requirements. They vary from brand to brand, so mixing brands in a circuit can cause a misfire and is not recommended. In a delay electric blasting cap, a delay element containing specially blended powders is interposed between the bridgewire and the primer charge. The delay element is accurately calibrated to give a specified time lapse between the application of electric current and the detonation of the base charge.

Two basic series of delays are available: (1) Short or millisecond

delays and (2) longer delays, often called slow delays. The millisecond delays have delay increments ranging from 25 to 50 milliseconds; the longer delays, from 0.5 to 1 second. In normal blasting, where maximum fragmentation is desired, millisecond delays produce good breakage and reduce airblast and ground vibrations. Slow delays are primarily for underground or tunnel work, where they provide enough time for rock movement between delay periods. Longer delays are likely to result in coarser fragmentation than millisecond delays.

### 2.7.3 Detonating Cord

Detonating cord consists of a core of high explosive, usually PETN, contained in a waterproof plastic sheath, enclosed in a reinforcing covering of various combinations of textile, plastic, wire, and waterproofing materials. The different reinforcing covers have different degrees of tensile strength, abrasion resistance, and

flexibility. Detonating cord with core loadings ranging from 1 gr/ft to 400 grains/ft of PETN is available for various uses. All grades can be detonated with a blasting cap and have a detonation velocity of about +22,000 fps.

A PETN core load of 50-gr/ft is used for most applications. However, 25 gr/ft detonating cord has become a satisfactory substitute. Its marked insensitivity to external shock and friction makes detonating cord ideal for use as both a downline and trunkline for primary blasting (Figure 2-5). The blasting cap need not be connected into the circuit until just before firing, eliminating most of the hazard of premature detonation.

A 25- or 50-gr/ft detonating cord detonates any cap sensitive explosive in contact with it but will not reliably detonate a blasting agent.

Detonating cord has wide application in underwater work. In a wet environment, the ends of the

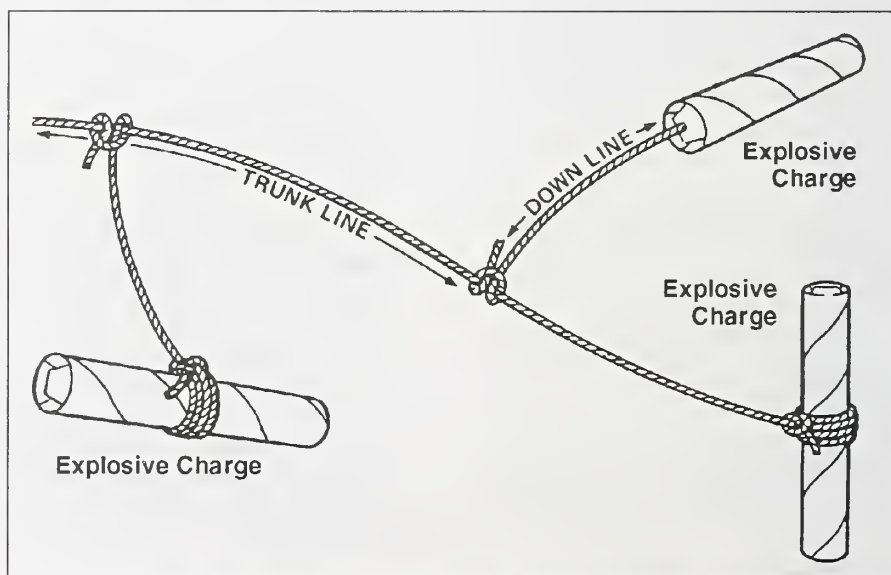


Figure 2-5.—Use of detonating cord for simultaneous nonelectric detonation of explosive charges.

detonating cord should be protected from water. PETN will slowly absorb water and become insensitive to initiation. Even when damp, however, detonating cord detonates if initiated on a dry end.

Millisecond delay connectors are available. The connectors are tied between two ends of detonating cord in the trunkline and permit the use of an unlimited number of delay periods. Delay connectors are commonly available in periods of 5,9,17, 25,35, and 45 milliseconds.

Detonating cord with a core load of 1 to 5 gr/ft of PETN, known as low-energy detonating cord or LEDC has two principal uses. The first is a trunkline where firing with detonating cord is desired or airblast presents a problem. LEDC produces virtually no airblast. The second use is a downline where center or bottom initiation is desired.

Detonating cord with core loads as high as 200 gr/ft are laced together to make fireline explosives with a combined loading of 1,400 gr/ft (see Chapter 6.2).

## 2.7.4 Nonel® Primadet

Nonel is a .12-inch diameter plastic tube with a thin reactive coating on the inside surface. When initiated with an EBW, EBC, or detonating cord, the tube transmits a low-energy signal from one point to another by means of a shock wave phenomenon similar to a dust explosion. It will propagate around sharp bends and through kinks. Because such a small amount of reactive material is used, the reaction will not initiate the explosives and the tube remains intact during and after functioning. Noise levels are very low.

Nonel is not initiated by stray currents, fire, or most light impact, shock, and friction hazards encountered in normal blasting work. However, shock initiators using 12-gauge primers are used to initiate Nonel.

Nonel is available in several factory-assembled lengths with non-electric delay detonators crimped on one end that will detonate cap-sensitive cartridge explosives.

## 2.7.5 Primers

With non-cap-sensitive blasting agents, the initiation sensitivity is so low that a primer (any cap sensitive explosive) is required to provide adequate initiation for the charge.

Primers are supplied in a variety of sizes (Figures 2-6 and 2-7) and are generally cast PETN. Provision are made for initiating the primer with det cord (usually a 25 or 50 gr/ft) or a No. 6 or No. 8 blasting cap (EWC or EBC)

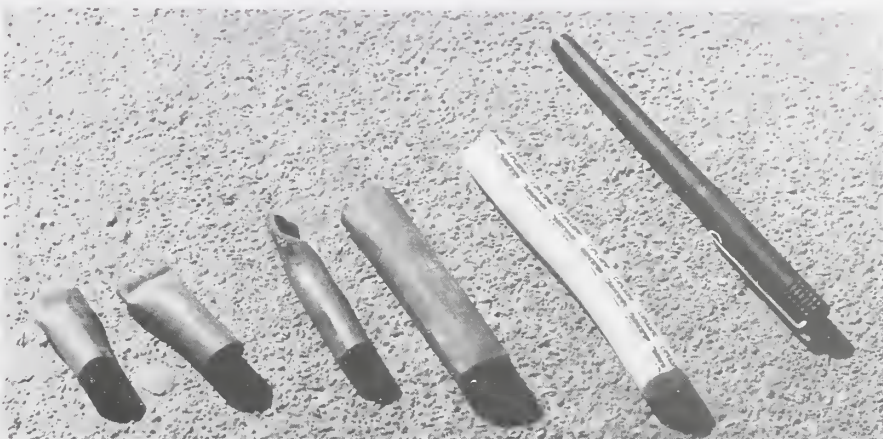
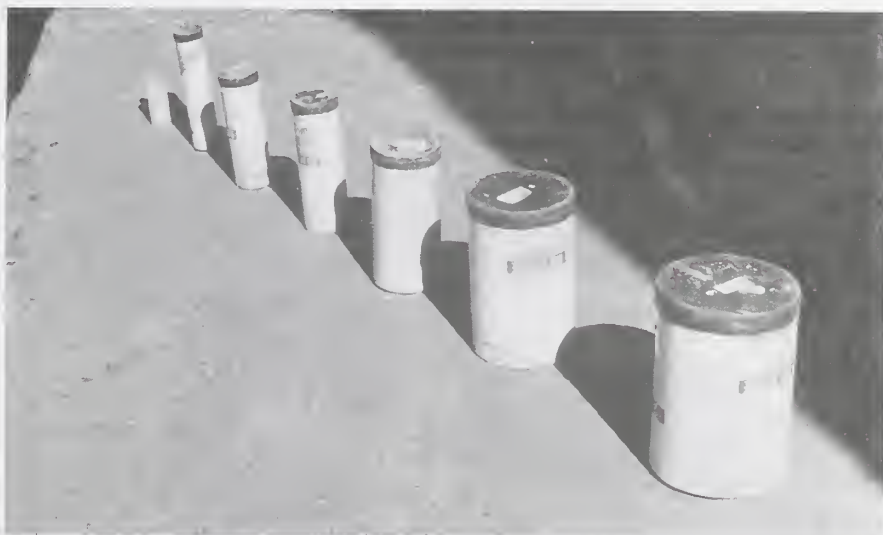
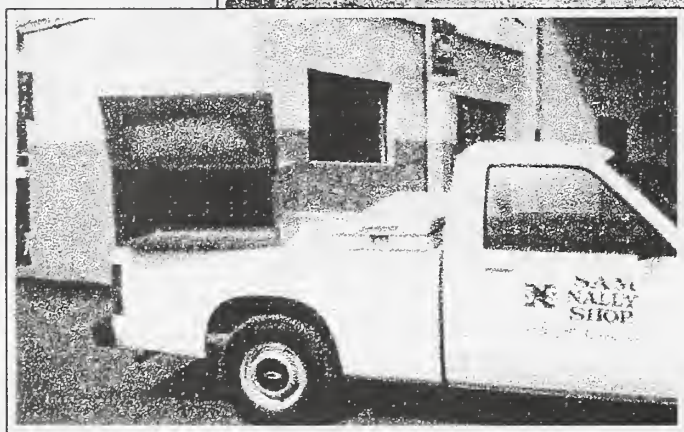
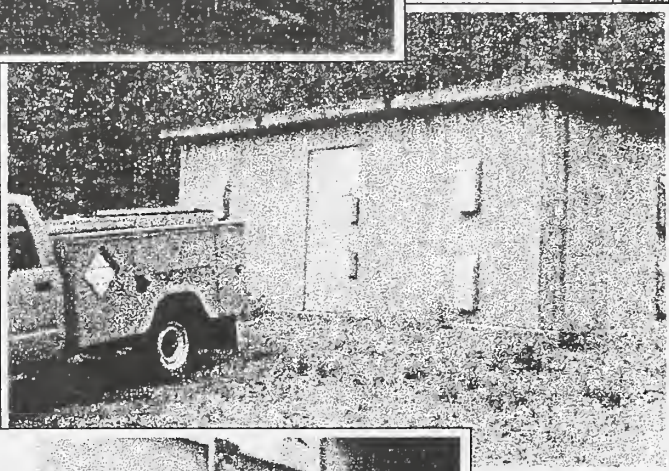
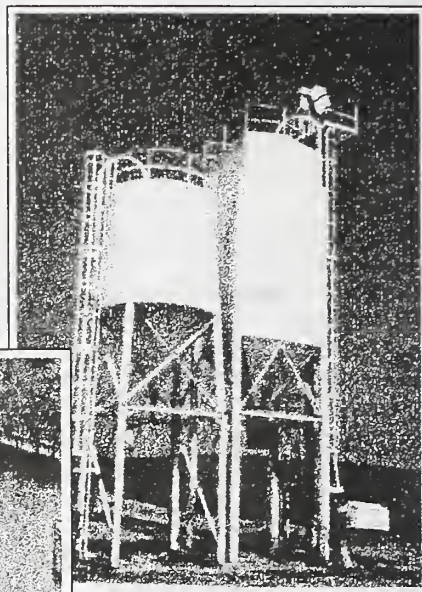
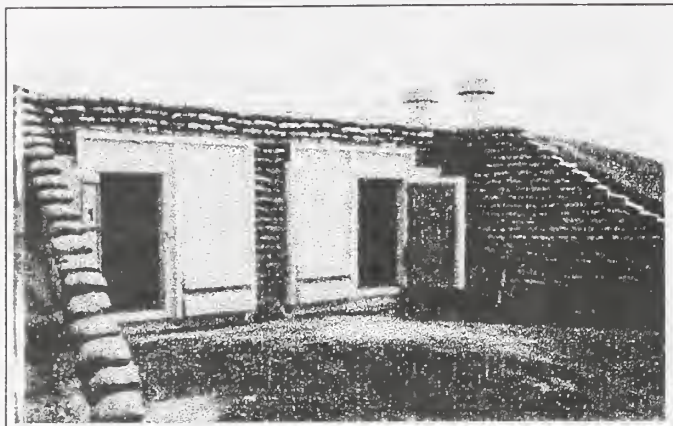


Figure 2-7.—Smaller series of primers.

## Chapter 3



## Section Contents

3.1 General	27
3.2 Storing Explosives In Remote, Uninhabited, Roadless Locations	27
3.3 Storing Fireline Explosives In The Field	27
3.4 Two-Component Cap-Sensitive Explosives	27
3.5 Permanent Magazine	27
3.5.1 27 CFR Part 55, Subpart K	27

separately behind natural barriers in an area out of sight and a safe distance from the trail. Make secure from theft as is practicable. Clear away leaves, dead grass, and other flammable materials. Protect explosives from water with fire-resistant waterproofed canvas; slope the ground to keep away surface water. Post explosives with red-on-white warning sign reading, “Explosives, Keep Off” in letters at least 1-1/2 inches high. Sign will be placed on or against the explosives but not where it is in view from the trail.

Transport only enough explosives to the work area to last for one work period (5 or 10 days). Do not leave explosives unattended for more than 12 hours. Where practical, transport magazines by plane or helicopter.

shall never be stored with the fireline explosives. In the event of a lightning storm, all personnel including the guard will move at least 1,000 feet from the storage area.

Only when absolutely necessary, when in a spike camp, and away from roads explosives may be stored as in *Section 3.2*.

## 3.4 Two-Component Cap-Sensitive Explosives

Store both components in an approved magazine. An approved magazine for two-component explosives is a locked cabinet for each component. However, when mixed it becomes a Class A explosive and must be stored according to *CFR 27 part 55*.

## 3.5 Permanent Magazine

Post magazines with signs reading “Explosives - Keep Off.” Locate signs to minimize the possibility of a bullet traveling in the direction of the magazine if anyone shoots at the sign.

Day boxes shall not be used for permanent storage.

### 3.5.1 27 CFR Part 55, Subpart K (see following):

## 3.1 General

Storage shall conform to *Part 55, Subpart K of Title 27 CFR (BATF)* Exceptions to *Title 27 CFR*, other than more stringent regulations of local, State, or Federal agencies, shall be approved by the Director of BATF (*See ATF P 5400.7*) dated 6/90.

For inspection and recordkeeping see *Sections 1.2 and 1.3, Chapter 1*.

## 3.2 Storing Explosives In Remote, Uninhabited, Roadless Locations

In remote, uninhabited, roadless locations (back country or wilderness), store explosives and detonators

## 3.3 Storing Fireline Explosives In The Field

Use portable type 2 (see 27 CFR Part 55, page 27) magazines where possible. A type 3 (see 27 CFR Part 55, page 27) magazine or an explosives transport truck may be used if storage distance and attendance regulations are adhered to and the truck is kept locked.

When it is not possible to store explosives in an approved magazine, the explosives will be stored in a secured area away from the camp. If possible, store explosives behind a natural or man-made barrier. The explosives shall be covered with a fire-resistant waterproof tarpaulin. The explosives shall be under constant surveillance by a guard. Post the explosives with clearly visible red-on-white warning signs reading, “Explosives - Keep Off.” Detonators

## 27 CFR, Part 55, Subpart K—Storage

### § 55.201 General.

(a) Section 842(j) of the Act and § 55.29 of this part require that the storage of explosive materials by any person must be in accordance with the regulations in this part. Further, section 846 of this Act authorizes regulations to prevent the recurrence of accidental explosions in which explosive materials were involved. The storage standards prescribed by this subpart confer no right or privileges to store explosive materials in a manner contrary to State or local law.

(b) The Director may authorize alternate construction for explosives storage magazines when it is shown that the alternate magazine construction is substantially equivalent to the standards of safety and security contained in this subpart. Any alternate explosive magazine construction approved by the Director prior to August 9, 1982, will continue as approved unless notified in writing by the Director. Any person intending to use alternate magazine construction shall submit a letter application to the regional director (compliance) for transmittal to the Director, specifically describing the proposed magazine. Explosive materials may not be stored in alternate magazines before the applicant has been notified that the application has been approved.

(c) A licensee or permittee who intends to make changes in his magazines, or who intends to construct or acquire additional magazines, shall comply with § 55.63.

(d) The regulations set forth in §§ 55.221 through 55.224 pertain to the storage of special fireworks, pyrotechnic compositions and explosive materials used in assembling fireworks.

(e) The provisions of § 55.202(a) classifying flash powder and bulk salutes as high explosives are mandatory after March 7, 1990:

Provided, that those persons who hold licenses or permits under this part on that date shall, with respect to the premises covered by such licenses or permits, comply with the high explosives storage requirements for flash powder and bulk salutes by March 7, 1991. [Amended by TD. ATF-293, 55 FR 3722, Feb. 5, 1990]

### § 55.202 Classes of explosive materials.

For purposes of this part, there are three classes of explosive materials. These classes, together with the description of explosive materials comprising each class, are as follows:

(a) **High explosives.** Explosive materials which can be caused to detonate by means of a blasting cap when unconfined, (for example, dynamite, flash powders, and bulk salutes). See also § 55.201(e).

(b) **Low explosives.** Explosive materials which can be caused to deflagrate when confined, (for example, black

powder, safety fuses, igniters, igniter cords, fuse lighters, and "special fireworks" defined as Class B explosives by U.S. Department of Transportation regulations in 49 CFR Part 173, except for bulk salutes).

(c) **Blasting agents.** (For example, ammonium nitrate-fuel oil and certain water gels (see also § 55.11). [Amended by TD. ATF-293, 55 FR 3722, Feb. 5, 1990]).

### § 55.203 Types of magazines.

For purposes of this part, there are five types of magazines. These types, together with the classes of explosive materials, as defined in § 55.202, which will be stored in them, are as follows:

(a) **Type 1 magazines.** Permanent magazines for the storage of high explosives, subject to the limitations prescribed by §§ 55.206 and 55.213. Other classes of explosive materials may also be stored in type 1 magazines.

(b) **Type 2 magazines.** Mobile and portable indoor and outdoor magazines for the storage of high explosives, subject to the limitations prescribed by §§ 55.206, 55.208(b), and 55.213. Other classes of explosive materials may also be stored in type 2 magazines.

(c) **Type 3 magazines.** Portable outdoor magazines for the temporary storage of high explosives while attended (for example, a "day-box"), subject to the limitations prescribed by §§ 55.206 and 55.213. Other classes of explosive materials may also be stored in type 3 magazines.

(d) **Type 4 magazines.** Magazines for the storage of low explosives, subject to the limitations prescribed by §§ 55.206(b), 55.210(b), and 55.213. Blasting agents may be stored in type 4 magazines, subject to the limitations prescribed by §§ 55.206(c), 55.211 (b), and 55.213. Detonators that will not mass detonate may also be stored in type 4 magazines, subject to the limitations prescribed by §§ 55.206(a), 55.210(b), and 55.213.

(e) **Type 5 magazines.** Magazines for the storage of blasting agents, subject to the limitations prescribed by §§ 55.206(c), 55.211(b), and 55.213.

### § 55.204 Inspection of magazines.

Any person storing explosive materials shall inspect their magazines at least every seven days. This inspection need not be an inventory, but must be sufficient to determine whether there has been unauthorized entry or attempted entry into the magazines, or unauthorized removal of the contents of the magazines.

### § 55.205 Movement of explosive materials.

All explosive materials must be kept in locked magazines meeting the standards in this subpart unless they are:

(a) In the process of manufacture;

- (b) Being physically handled in the operating process of a licensee or user;
- (c) Being used; or
- (d) Being transported to a place of storage or use by a licensee or permittee or by a person who has lawfully acquired explosive materials under § 55.106.

#### § 55.206 Location of magazines.

- (a) Outdoor magazines in which high explosives are stored must be located no closer to inhabited buildings, passenger railways, public highways, or other magazines in which high explosives are stored, than the minimum distances specified in the table of distances for storage of explosive materials in § 55.218.
- (b) Outdoor magazines in which low explosives are stored must be located no closer to inhabited buildings, passenger railways, public highways, or other magazines in which explosive materials are stored, than the minimum distances specified in the table of distances for storage of low explosives in § 55.219, except that the table of distances in § 55.224 shall apply to the storage of special fireworks. The distances shown in § 55.219 may not be reduced by the presence of barricades.
- (c)(1) Outdoor magazines in which blasting agents in quantities of more than 50 pounds are stored must be located no closer to inhabited buildings, passenger railways, or public highways than the minimum distances specified in the table of distances for storage of explosive materials in § 55.218.
- (c)(2) Ammonium nitrate and magazines in which blasting agents are stored must be located no closer to magazines in which high explosives or other blasting agents are stored than the minimum distances specified in the table of distances for the separation of ammonium nitrate and blasting agents in § 55.220. However, the minimum distances for magazines in which explosives and blasting agents are stored from inhabited buildings, etc., may not be less than the distances specified in the table of distances for storage of explosives materials in § 55.218. [Amended by T.D. ATF-293, 55 FR 3722, Feb. 5, 1990]

#### § 55.207 Construction of type 1 magazines.

A type 1 magazine is a permanent structure: a building, an igloo or "Army-type structure", a tunnel, or a dugout. It is to be bullet-resistant, fire-resistant, weather-resistant, theft-resistant, and ventilated.

- (a) **Buildings.** All building type magazines are to be constructed of masonry, wood, metal, or a combination of these materials, and have no openings except for entrances and ventilation. The ground around building magazines must slope away for drainage or other adequate drainage provided.

**(a)(1) Masonry wall construction.** Masonry wall construction is to consist of brick, concrete, tile, cement block, or cinder block and be not less than 6 inches in thickness. Hollow masonry units used in construction must have all hollow spaces filled with well-tamped, coarse, dry sand or weak concrete (at least a mixture of one part cement and eight parts of sand with enough water to dampen the mixture while tamping in place). Interior walls are to be constructed of, or covered with, a nonsparking material.

**(a)(2) Fabricated metal wall construction.** Metal wall construction is to consist of sectional sheets of steel or aluminum not less than number 14-gauge, securely fastened to a metal framework. Metal wall construction is either lined inside with brick, solid cement blocks, hardwood not less than four inches thick, or will have at least a six inch sand fill between interior and exterior walls. Interior walls are to be constructed of, or covered with, a nonsparking material.

**(a)(3) Wood frame wall construction.** The exterior of outer wood walls is to be covered with iron or aluminum not less than number 26-gauge. An inner wall of, or covered with nonsparking material, will be constructed so as to provide a space of not less than six inches between the outer and inner walls. The space is to be filled with coarse, dry sand or weak concrete.

**(a)(4) Floors.** Floors are to be constructed of, or covered with, a nonsparking material and shall be strong enough to bear the weight of the maximum quantity to be stored. Use of pallets covered with a nonsparking material is considered equivalent to a floor constructed of or covered with a nonsparking material.

**(a)(5) Foundations.** Foundations are to be constructed of brick, concrete, cement block, stone, or wood posts. If piers or posts are used, in lieu of a continuous foundation, the space under the buildings is to be enclosed with metal.

**(a)(6) Roof.** Except for buildings with fabricated metal roofs, the outer roof is to be covered with no less than number 26-gauge iron or aluminum, fastened to at least 7/8 inch sheathing.

**(a)(7) Bullet-resistant ceilings or roofs.** Where it is possible for a bullet to be fired directly through the roof and into the magazine at such an angle that the bullet would strike the explosives within, the magazine is to be protected by one of the following methods:

- (i) *A sand tray lined with a layer of building paper, plastic, or other nonporous material, and filled with not less than four inches of coarse, dry sand, and located at the tops of inner walls covering the entire ceiling area, except that portion necessary for ventilation.*
- (ii) *A fabricated metal roof constructed of 3/16-inch plate steel lined with four inches of hardwood. (For each additional 1/16-inch of plate steel, the hardwood lining may be decreased one inch.)*

**(a)(8) Doors.** All doors are to be constructed of not less than 1/4-inch plate steel and lined with at least two inches of hardwood. Hinges and hasps are to be attached to the doors by welding, riveting or bolting (nuts on inside of door). They are to be installed in such a manner that the hinges and hasps cannot be removed when the doors are closed and locked.

**(a)(9) Locks.** Each door is to be equipped with:

- (i) Two mortise locks;*
- (ii) Two padlocks fastened in separate hasps and staples;*
- (iii) A combination of a mortise lock and a padlock;*
- (iv) A mortise lock that requires two keys to open; or,*
- (v) A three-point lock.*

Padlocks must have at least five tumblers and a case-hardened shackle of at least 3/8-inch diameter. Padlocks must be protected with not less than 1/4-inch steel hoods constructed so as to prevent sawing or lever action on the locks, hasps, and staples.

These requirements do not apply to magazine doors that are adequately secured on the inside by means of a bolt, lock, or bar that cannot be actuated from the outside.

**(a)(10) Ventilation.** Ventilation is to be provided to prevent dampness and heating of stored explosive materials.

Ventilation openings must be screened to prevent the entrance of sparks. Ventilation openings in side walls and foundations must be offset or shielded for bullet-resistant purposes. Magazines having foundation and roof ventilators with the air circulating between the side walls and the floors and between the side walls and the ceiling must have a wooden lattice lining or equivalent to prevent the packages of explosive materials from being stacked against the side walls and blocking the air circulation.

**(a)(11) Exposed metal.** No sparking material is to be exposed to contact with the stored explosive materials. All ferrous metal nails in the floor and side walls, which might be exposed to contact with explosive materials, must be blind nailed, countersunk, or covered with a nonsparking lattice work or other nonsparking material.

**(b) Igloos, "Army-type structures", tunnels, and dugouts.** Igloo, "Army-type structure", tunnel, and dugout magazines are to be constructed of reinforced concrete, masonry, metal, or a combination of these materials. They must have an earthmound covering of not less than 24 inches on the top, sides, and rear unless the magazine meets the requirements of paragraph (a)(7) of this section. Interior walls and floors must be constructed of, or covered with, a nonsparking material. Magazines of this type are also to be constructed in conformity with the requirements of paragraph (a)(4) and paragraphs (a)(8) through (11) of this section.

#### **§ 55.208 Construction of type 2 magazines.**

A type 2 magazine is a box, trailer, semitrailer, or other mobile facility.

**(a) Outdoor magazines.**

**(a)(1) General.** Outdoor magazines are to be bullet-resistant, fire-resistant, weather-resistant, theft-resistant, and ventilated. They are to be supported to prevent direct contact with the ground and, if less than one cubic yard in size, must be securely fastened to a fixed object. The ground around outdoor magazines must slope away for drainage or other adequate drainage provided. When unattended, vehicular magazines must have wheels removed or otherwise effectively immobilized by kingpin locking devices or other methods approved by the Director.

**(a)(2) Exterior construction.** The exterior and doors are to be constructed of not less than 1/4-inch steel and lined with at least two inches of hardwood. Magazines with top openings will have lids with water-resistant seals or which overlap the sides by at least one inch when in a closed position.

**(a)(3) Hinges and hasps.** Hinges and hasps are to be attached to doors by welding, riveting, or bolting (nuts on inside of door). Hinges and hasps must be installed so that they cannot be removed when the doors are closed and locked.

**(a)(4) Locks.** Each door is to be equipped with:

- (i) Two mortise locks;*
- (ii) Two padlocks fastened in separate hasps and staples;*
- (iii) A combination of a mortise lock and a padlock;*
- (iv) A mortise lock that requires two keys to open; or,*
- (v) A three-point lock.*

Padlocks must have at least five tumblers and a case-hardened shackle of at least 3/8-inch diameter. Padlocks must be protected with not less than 1/4-inch steel hoods constructed so as to prevent sawing or lever action on the locks, hasps, and staples.

These requirements do not apply to magazine doors that are adequately secured on the inside by means of a bolt, lock, or bar that cannot be actuated from the outside.

**(b) Indoor magazines.**

**(b)(1) General.** Indoor magazines are to be fire-resistant and theft-resistant. They need not be bullet-resistant and weather-resistant if the buildings in which they are stored provide protection from the weather and from bullet penetration.

No indoor magazine is to be located in a residence or dwelling. The indoor storage of high explosives must not exceed a quantity of 50 pounds. More than one indoor magazine may be located in the same building if the total quantity of explosive materials stored does not exceed 50 pounds. Detonators must be stored in a separate magazine (except as provided in § 55.213) and the total quantity of detonators must not exceed 5,000.

**(b)(2) Exterior construction.** Indoor magazines are to be constructed of wood or metal according to one of the following specifications:

(i) Wood indoor magazines are to have sides, bottoms and doors constructed of at least two inches of hardwood and are to be well braced at the corners. They are to be covered with sheet metal of not less than number 26-gauge (.0179 inches). Nails exposed to the interior of magazines must be countersunk.

(ii) Metal indoor magazines are to have sides, bottoms and doors constructed of not less than number 12-gauge (.1046 inches) metal and be lined inside with a nonsparking material. Edges of metal covers must overlap sides at least one inch.

**(b)(3) Hinges and hasps.** Hinges and hasps are to be attached to doors by welding, riveting, or bolting (nuts on inside of door). Hinges and hasps must be installed so that they cannot be removed when the doors are closed and locked.

**(b)(4) Locks.** Each door is to be equipped with:

- (i) *Two mortise locks;*
- (ii) *Two padlocks fastened in separate hasps and staples;*
- (iii) *A combination of a mortise lock and a padlock;*
- (iv) *A mortise lock that requires two keys to open; or,*
- (v) *A three-point lock.*

Padlocks must have at least five tumblers and a case-hardened shackle of at least 3~8 inch diameter. Padlocks must be protected with not less than 1/4 inch steel hoods constructed so as to prevent sawing or lever action on the locks, hasps, and staples.

Indoor magazines located in secure rooms that are locked as provided in this subparagraph may have each door locked with one steel padlock (which need not be protected by a steel hood) having at least five tumblers and a case-hardened shackle of at least 3~8 inch diameter, if the door hinges and lock hasps are securely fastened to the magazine.

These requirements do not apply to magazine doors that are adequately secured on the inside by means of a bolt, lock, or bar that cannot be actuated from the outside.

**(c) Detonator boxes.** Magazines for detonators in quantities of 100 or less are to have sides, bottoms and doors constructed of not less than number 12-gauge (.1046 inches) metal and lined with a nonsparking material. Hinges and hasps must be attached so they cannot be removed from the outside. One steel padlock (which need not be protected by a steel hood) having at least five tumblers and a case-hardened shackle of at least 3~ inch diameter is sufficient for locking purposes.

#### § 55.209 Construction of type 3 magazines.

A type 3 magazine is a "day-box" or other portable magazine. It must be fire-resistant, weather-resistant, and theft-resistant. A type 3 magazine is to be constructed of not less than number 12-gauge (.1046) steel, lined with at

least either 1/2-inch plywood or 1/2-inch Masonite-type hardboard.

Doors must overlap door openings by at least one inch. Hinges and hasps are to be attached by welding, riveting or bolting (nuts on inside).

One steel padlock (which need not be protected by a steel hood) having at least five tumblers and a case-hardened shackle of at least 3-inch diameter is sufficient for locking purposes. Explosive materials are not to be left unattended in type 3 magazines and must be removed to type 1 or 2 magazines for unattended storage.

#### § 55.210 Construction of type 4 magazines.

A type 4 magazine is a building, igloo, or "Army type structure," tunnel, dugout, box, trailer, or a semitrailer or other mobile magazine.

**(a) Outdoor magazines.**

**(a)(1) General.** Outdoor magazines are to be fire-resistant, weather-resistant, and theft-resistant. The ground around outdoor magazines must slope away for drainage or other adequate drainage be provided. When unattended, vehicular magazines must have wheels removed or otherwise be effectively immobilized by kingpin locking devices or other methods approved by the Director.

**(a)(2) Construction.** Outdoor magazines are to be constructed of masonry, metal-covered wood, fabricated metal, or a combination of these materials. Foundations are to be constructed of brick, concrete, cement block, stone, or metal or wood posts. If piers or posts are used in lieu of a continuous foundation, the space under the building is to be enclosed with fire-resistant material. The walls and floors are to be constructed of, or covered with, a nonsparking material or lattice work. The doors must be metal or solid wood covered with metal.

**(a)(3) Hinges and hasps.** Hinges and hasps are to be attached to doors by welding, riveting, or bolting (nuts on inside of door). Hinges and hasps must be installed so that they cannot be removed when the doors are closed and locked.

**(a)(4) Locks.** Each door is to be equipped with:

- (i) *Two mortise locks;*
- (ii) *Two padlocks fastened in separate hasps and staples;*
- (iii) *A combination of a mortise lock and a padlock;*
- (iv) *A mortise lock that requires two keys to open; or,*
- (v) *A three-point lock.*

Padlocks must have at least five tumblers and a case-hardened shackle of at least 3/8-inch diameter. Padlocks must be protected with not less than 1/4-inch steel hoods constructed so as to prevent sawing or lever action on the locks, hasps, and staples.

These requirements do not apply to magazine doors that are adequately secured on the inside by means of a bolt, lock, or bar that cannot be actuated from the outside.

**(b) Indoor magazines.**

**(b)(1) General.** Indoor magazines are to be fire-resistant and theft-resistant. They need not be weather-resistant if the buildings in which they are stored provide protection from the weather.

No indoor magazine is to be located in a residence or dwelling. The indoor storage of low explosives must not exceed a quantity of 50 pounds. More than one indoor magazine may be located in the same building if the total quantity of explosive materials stored does not exceed 50 pounds. Detonators that will not mass detonate must be stored in a separate magazine and the total number of electric detonators must not exceed 5,000.

**(b)(2) Construction.** Indoor magazines are to be constructed of masonry, metal-covered wood, fabricated metal, or a combination of these materials. The walls and floors are to be constructed of, or covered with, a nonsparking material. The doors must be metal or solid wood covered with metal.

**(b)(3) Hinges and hasps.** Hinges and hasps are to be attached to doors by welding, riveting, or bolting (nuts on inside of door). Hinges and hasps must be installed so that they cannot be removed when the doors are closed and locked.

**(b)(4) Locks.** Each door is to be equipped with:

- (i) *Two mortise locks;*
- (ii) *Two padlocks fastened in separate hasps and staples;*
- (iii) *A combination of a mortise lock and a padlock;*
- (iv) *A mortise lock that requires two keys to open; or,*
- (v) *A three-point lock.*

Padlocks must have at least five tumblers and a case-hardened shackle of at least 3/8-inch diameter. Padlocks must be protected with not less than 1/4-inch steel hoods constructed so as to prevent sawing or lever action on the locks, hasps, and staples.

Indoor magazines located in secure rooms that are locked as provided in this subparagraph may have each door locked with one steel padlock (which need not be protected by a steel hood) having at least five tumblers and a case-hardened shackle of at least 3/8-inch diameter, if the door hinges and lock hasps are securely fastened to the magazine.

These requirements do not apply to magazine doors that are adequately secured on the inside by means of a bolt, lock, or bar that cannot be actuated from the outside.

**§ 55.211 Construction of type 5 magazines.**

A type 5 magazine is a building, igloo, or "Armytype structure," tunnel, dugout, box, trailer, or a semitrailer or other mobile facility.

**(a) Outdoor magazines.**

**(a)(1) General.** Outdoor magazines are to be weather-resistant, and theft-resistant. The ground around magazines must slope away for drainage or other adequate

drainage be provided. When unattended, vehicular magazines must have wheels removed or otherwise be effectively immobilized by kingpin locking devices or other methods approved by the Director.

**(a)(2) Construction.** The doors are to be constructed of solid wood or metal.

**(a)(3) Hinges and hasps.** Hinges and hasps are to be attached to doors by welding, riveting, or bolting (nuts on inside of door). Hinges and hasps must be installed so that they cannot be removed when the doors are closed and locked.

**(a)(4) Locks.** Each door is to be equipped with:

- (i) *Two mortise locks;*
- (ii) *Two padlocks fastened in separate hasps and staples;*
- (iii) *A combination of a mortise lock and a padlock;*
- (iv) *A mortise lock that requires two keys to open; or,*
- (v) *A three-point lock.*

Padlocks must have at least five tumblers and a case-hardened shackle of at least 3/8-inch diameter. Padlocks must be protected with not less than 1/4-inch steel hoods constructed so as to prevent sawing or lever action on the locks, hasps, and staples.

Trailers, semitrailers, and similar vehicular magazines may, for each door, be locked with one steel padlock (which need not be protected by a steel hood) having at least five tumblers and a casehardened shackle of at least 3/8-inch diameter, if the door hinges and lock hasps are securely fastened to the magazine and to the door frame. These requirements do not apply to magazine doors that are adequately secured on the inside by means of a bolt, lock, or bar that cannot be actuated from the outside.

**(a)(5) Placards.** The placards required by Department of Transportation regulations at 49 CFR Part 172, Subpart F, for the transportation of blasting agents shall be displayed on all magazines.

**(b) Indoor magazines.**

**(b)(1) General.** Indoor magazines are to be theft-resistant. They need not be weather-resistant if the buildings in which they are stored provide protection from the weather. No indoor magazine is to be located in a residence or dwelling. Indoor magazines containing quantities of blasting agents in excess of 50 pounds are subject to the requirements of § 55.206 of this subpart.

**(b)(2) Construction.** The doors are to be constructed of wood or metal.

**(b)(3) Hinges and hasps.** Hinges and hasps are to be attached to doors by welding, riveting, or bolting (nuts on inside). Hinges and hasps must be installed so that they cannot be removed when the doors are closed and locked.

**(b)(4) Locks.** Each door is to be equipped with:

- (i) *Two mortise locks;*
- (ii) *Two padlocks fastened in separate hasps and staples;*
- (iii) *A combination of a mortise lock and a padlock;*

- (iv) A mortise lock that requires two keys to open; or,
- (v) A three-point lock.

Padlocks must have at least five tumblers and a case-hardened shackle of at least 3/8-inch diameter. Padlocks must be protected with not less than 1/4-inch steel hoods constructed so as to prevent sawing or lever action on the locks, hasps, and staples.

Indoor magazines located in secure rooms that are locked as provided in this subparagraph may have each door locked with one steel padlock (which need not be protected by a steel hood) having at least five tumblers and a case-hardened shackle of at least 3/8-inch diameter, if the door hinges and lock hasps are securely fastened to the magazine and to the door frame.

These requirements do not apply to magazine doors that are adequately secured on the inside by means of a bolt, lock, or bar that cannot be actuated from the outside.

[Amended by *T.D. ATF-298, 55 FR 21862*, May 30, 1990]

#### **§ 55.212 Smoking and open flames.**

Smoking, matches, open flames, and spark producing devices are not permitted:

- (a) In any magazine;
- (b) Within 50 feet of any outdoor magazine; or
- (c) Within any room containing an indoor magazine.

#### **§ 55.213 Quantity and storage restrictions.**

(a) Explosive materials in excess of 300,000 pounds or detonators in excess of 20 million are not to be stored in one magazine unless approved by the Director.

(b) Detonators are not to be stored in the same magazine with other explosive materials, except under the following circumstances:

(b)(1) In a type 4 magazine, detonators that will not mass detonate may be stored with electric squibs, safety fuse, igniters, and igniter cord.

(b)(2) In a type 1 or type 2 magazine, detonators may be stored with delay devices and any of the items listed in paragraph (b)(1) of this section.

#### **§ 55.214 Storage within types 1, 2, 3, and 4 magazines.**

(a) Explosive materials within a magazine are not to be placed directly against interior walls and must be stored so as not to interfere with ventilation. To prevent contact of stored explosive materials with walls, a nonsparking lattice work or other nonsparking material may be used.

(b) Containers of explosive materials are to be stored so that marks are visible. Stocks of explosive materials are to be stored so they can be easily counted and checked upon inspection.

(c) Except with respect to fiberboard or other nonmetal containers, containers of explosive materials are not to be unpacked or repacked inside a magazine or within 50 feet of a magazine, and must not be unpacked or repacked

close to other explosive materials. Containers of explosive materials must be closed while being stored.

(d) Tools used for opening or closing containers of explosive materials are to be of nonsparking materials, except that metal slitters may be used for opening fiberboard containers. A wood wedge and a fiber, rubber, or wooden mallet are to be used for opening or closing wood containers of explosive materials. Metal tools other than nonsparking transfer conveyors are not to be stored in any magazine containing high explosives.

#### **§ 55.215 Housekeeping.**

Magazines are to be kept clean, dry, and free of grit, paper, empty packages and containers, and rubbish. Floors are to be regularly swept. Brooms and other utensils used in the cleaning and maintenance of magazines must have no sparkproducing metal parts, and may be kept in magazines. Floors stained by leakage from explosive materials are to be cleaned according to instructions of the explosives manufacturer. When any explosive material has deteriorated it is to be destroyed in accordance with the advice or instructions of the manufacturer. The area surrounding magazines is to be kept clear of rubbish, brush, dry grass, or trees (except live trees more than 10 feet tall), for not less than 25 feet in all directions. Volatile materials are to be kept a distance of not less than 50 feet from outdoor magazines. Living foliage which is used to stabilize the earthen covering of a magazine need not be removed.

#### **§ 55.216 Repair of magazines.**

Before repairing the interior of magazines, all explosive materials are to be removed and the interior cleaned.

Before repairing the exterior of magazines, all explosive materials must be removed if there exists any possibility that repairs may produce sparks or flame. Explosive materials removed from magazines under repair must be:

- (a) Placed in other magazines appropriate for the storage of those explosive materials under this subpart, or
- (b) Placed a safe distance from the magazines under repair where they are to be properly guarded and protected until the repairs have been completed.

#### **§ 55.217 Lighting.**

(a) Battery-activated safety lights or battery-activated safety lanterns may be used in explosives storage magazines.

(b) Electric lighting used in any explosives storage magazine must meet the standards prescribed by the "National Electrical Code," (National Fire Protection Association, NFPA 70-81), for the conditions present in the magazine at any time. All electrical switches are to be located outside of the magazine and also meet the standards prescribed by the National Electrical Code.

(c) Copies of invoices, work orders or similar documents which indicate the lighting complies with the National

Electrical Code must be available for inspection by ATF officers.

§ 55.218 Table of distances for storage of explosive materials.

QUANTITY OF EXPLOSIVES		DISTANCES (IN FEET)							
(IN POUNDS)		INHABITED BUILDINGS		PUBLIC HIGHWAYS, CLASS A to D**		PASSENGER RAILWAYS & PUBLIC HIGHWAYS, With traffic volume of more than 3,000 vehicles per day		SEPARATION OF MAGAZINES	
OVER	NOT OVER	BARRICADED	UNBARRICADED	BARRICADED	UNBARRICADED	BARRICADED	UNBARRICADED	BARRICADED	UNBARRICADED
2	5	70	140	30	60	51	102	6	12
5	10	90	180	35	70	64	128	8	16
10	20	110	220	45	90	81	162	10	20
20	30	125	250	50	100	93	186	11	22
30	40	140	280	55	110	103	206	12	24
40	50	150	300	60	120	110	220	14	28
50	75	170	340	70	140	127	254	15	30
75	100	190	380	75	150	139	278	16	32
100	125	200	400	80	160	150	300	18	36
125	150	215	430	85	170	159	318	19	38
150	200	235	470	95	190	175	350	21	42
200	250	255	510	105	210	189	378	23	46
250	300	270	540	110	220	201	402	24	48
300	400	295	590	120	240	221	442	27	54
400	500	320	640	130	260	238	476	29	58
500	600	340	680	135	270	253	506	31	62
600	700	355	710	145	290	266	532	32	64
700	800	375	750	150	300	278	556	33	66
800	900	390	780	155	310	289	578	35	70
900	1,000	400	800	160	320	300	600	36	72
1,000	1,200	425	850	165	330	318	636	39	78
1,200	1,400	450	900	170	340	338	672	41	82
1,400	1,600	470	940	175	350	351	702	43	86
1,600	1,800	490	980	180	360	366	732	44	88
1,800	2,000	505	1,010	185	370	378	756	45	90
2,000	2,500	545	1,090	190	380	408	816	49	98
2,500	3,000	580	1,160	195	390	432	864	52	104
3,000	4,000	635	1,270	210	420	474	948	58	118
4,000	5,000	685	1,370	225	450	513	1,026	61	122
5,000	8,000	730	1,480	235	470	546	1,092	65	130
6,000	7,000	770	1,540	245	490	573	1,146	68	136
7,000	8,000	800	1,600	250	500	600	1,200	72	144
8,000	9,000	835	1,670	255	510	624	1,248	75	150
9,000	10,000	865	1,730	260	520	645	1,290	78	156
10,000	12,000	875	1,750	270	540	687	1,374	82	164
12,000	14,000	885	1,770	275	550	723	1,446	87	174
14,000	16,000	900	1,800	280	560	758	1,512	90	180
16,000	18,000	940	1,880	285	570	785	1,572	94	188
18,000	20,000	975	1,950	290	580	813	1,626	98	196
20,000	25,000	1,055	2,000	315	630	876	1,752	105	210
25,000	30,000	1,130	2,000	340	680	933	1,866	112	224
30,000	35,000	1,205	2,000	360	720	981	1,962	119	238
35,000	40,000	1,275	2,000	380	760	1,026	2,000	124	248
40,000	45,000	1,340	2,000	400	800	1,068	2,000	129	258
45,000	50,000	1,400	2,000	420	840	1,104	2,000	135	270
50,000	55,000	1,460	2,000	440	880	1,140	2,000	140	280
55,000	60,000	1,515	2,000	455	910	1,173	2,000	145	290
60,000	65,000	1,565	2,000	470	940	1,206	2,000	150	300
65,000	70,000	1,610	2,000	485	970	1,236	2,000	155	310
70,000	75,000	1,655	2,000	500	1,000	1,263	2,000	160	320
75,000	80,000	1,695	2,000	510	1,020	1,293	2,000	165	330
80,000	85,000	1,730	2,000	520	1,040	1,317	2,000	170	340
85,000	90,000	1,760	2,000	530	1,060	1,344	2,000	175	350
90,000	95,000	1,790	2,000	540	1,080	1,368	2,000	180	360
95,000	100,000	1,815	2,000	545	1,090	1,392	2,000	185	370
100,000	110,000	1,835	2,000	550	1,100	1,437	2,000	195	390
110,000	120,000	1,855	2,000	555	1,110	1,479	2,000	205	410
120,000	130,000	1,875	2,000	560	1,120	1,521	2,000	215	430
130,000	140,000	1,890	2,000	565	1,130	1,557	2,000	225	450
140,000	150,000	1,900	2,000	570	1,140	1,593	2,000	235	470
150,000	160,000	1,935	2,000	580	1,160	1,629	2,000	245	490
160,000	170,000	1,965	2,000	590	1,180	1,662	2,000	255	510
170,000	180,000	1,990	2,000	600	1,200	1,695	2,000	265	530
180,000	190,000	2,010	2,010	605	1,210	1,725	2,000	275	550
190,000	200,000	2,030	2,030	610	1,220	1,755	2,000	285	570
200,000	210,000	2,055	2,055	620	1,240	1,782	2,000	295	590
210,000	230,000	2,100	2,100	635	1,270	1,838	2,000	315	630
230,000	250,000	2,155	2,155	650	1,300	1,890	2,000	335	670
250,000	275,000	2,215	2,215	670	1,340	1,950	2,000	360	720
275,000	300,000	2,275	2,275	690	1,380	2,000	2,000	385	770

\*\* = See § 55.11, "Highway."

**Notes to the Table of Distances for Storage of Explosives, above:**

(1) Terms found in the table of distances for storage of explosive materials are defined in § 55.11.

(2) When two or more storage magazines are located on the same property, each magazine must comply with the minimum distances specified from inhabited buildings, railways, and highways, and, in addition, they should be separated from each other by not less than the distances shown for "**Separation of Magazines**," except that the quantity of explosives contained in cap magazines shall govern in regard to the spacing of said cap magazines from magazines containing other explosives. If any two or more magazines are separated from each other by less than the specified "**Separation of Magazines**" distances,

then such two or more magazines, as a group must be considered as one magazine and the total quantity of explosives stored in such group must be treated as if stored in a single magazine located on the site of any magazine of the group and must comply with the minimum of distances specified from other magazines, inhabited buildings, railways, and highways.

(3) All types of blasting caps in strengths through No. 8 cap should be rated at 1 to 2 lbs. of explosives per 1,000 caps. For strengths higher than No. 8 cap, consult the manufacturer.

(4) For quantity and distance purposes, detonating cord of 50 or 60 grains per foot should be calculated as equivalent to 9 lbs. of high explosives per 1,000 feet. Heavier or lighter core loads should be rated proportionately.

§ 55.219 Table of distances for storage of low explosives.

POUNDS		DISTANCES IN FEET		
OVER	NOT OVER	FROM INHABITED BUILDING	FROM PUBLIC RAILROAD AND HIGHWAY	FROM ABOVE-GROUND MAGAZINE
0	1,000	75	75	50
1,000	5,000	115	115	75
5,000	10,000	150	150	100
10,000	20,000	190	190	125
20,000	30,000	215	215	145
30,000	40,000	235	235	155
40,000	50,000	250	250	165
50,000	60,000	260	260	175
60,000	70,000	270	270	185
70,000	80,000	280	280	190
80,000	90,000	295	295	195
90,000	100,000	300	300	200
100,000	200,000	375	375	250
200,000	300,000	450	450	300

§ 55.220 Table of separation distances of ammonium nitrate and blasting agents from explosives or blasting agents.

DONOR WEIGHT (POUNDS)		MINIMUM SEPARATION DISTANCE OF ACCEPTOR FROM DONOR WHEN BARRICADED (FEET)		MINIMUM THICKNESS OF ARTIFICIAL BARRICADES (INCHES)
OVER	NOT OVER	AMMONIUM NITRATE	BLASTING AGENT	
0	100	3	11	12
100	300	4	14	12
300	600	5	18	12
600	1,000	6	22	12
1,000	1,600	7	25	12
1,600	2,000	8	29	12
2,000	3,000	9	32	15
3,000	4,000	10	36	15
4,000	6,000	11	40	15
6,000	8,000	12	43	20
8,000	10,000	13	47	20
10,000	12,000	14	50	20
12,000	16,000	15	54	25
16,000	20,000	16	58	25
20,000	25,000	18	65	25
25,000	30,000	19	68	30
30,000	35,000	20	72	30
35,000	40,000	21	76	30
40,000	45,000	22	79	35
45,000	50,000	23	83	35
50,000	55,000	24	86	35
55,000	60,000	25	90	35
60,000	70,000	26	94	40
70,000	80,000	28	101	40
80,000	90,000	30	108	40
90,000	100,000	32	115	40
100,000	120,000	34	122	50
120,000	140,000	37	133	50
140,000	160,000	40	144	50
160,000	180,000	44	158	50
180,000	200,000	48	173	50
200,000	220,000	52	187	60
220,000	250,000	56	202	60
250,000	275,000	60	216	60
275,000	300,000	64	230	60

**Notes to the Table of Separation Distances of Ammonium Nitrate and Blasting Agents From Explosives or Blasting Agents:**

(1) This table specifies separation distances to prevent explosion of ammonium nitrate and ammonium nitrate-based blasting agents by propagation from nearby stores of high explosives or blasting agents referred to in the table as the "donor." Ammonium nitrate, by itself, is not considered to be a donor when applying this table. Ammonium nitrate, ammonium nitrate-fuel oil or combinations thereof are acceptors. If stores of ammonium nitrate are located within the sympathetic detonation distance of explosives or blasting agents, one-half the mass of the

ammonium nitrate is to be included in the mass of the donor.

(2) When the ammonium nitrate and/or blasting agent is not barricaded, the distances shown in the table must be multiplied by six. These distances allow for the possibility of high velocity metal fragments from mixers, hoppers, truck bodies, sheet metal structures, metal containers, and the like which may enclose the "donor." Where explosives storage is in bullet-resistant magazines or where the storage is protected by a bullet-resistant wall, distances and barricade thicknesses in excess of those prescribed in the table in § 55.218 are not required.

(3) These distances apply to ammonium nitrate that passes the insensitivity test prescribed in the definition of ammonium nitrate fertilizer issued by the Fertilizer Institute.

---

Ammonium nitrate failing to pass the test must be stored at separation distances in accordance with the table in § 55.218.

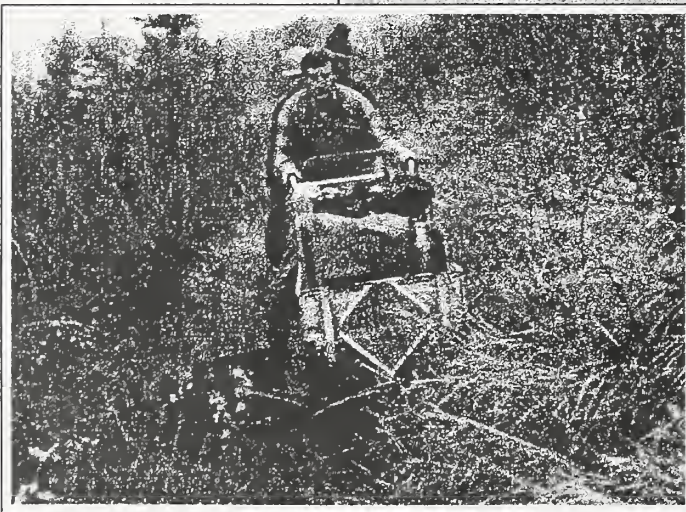
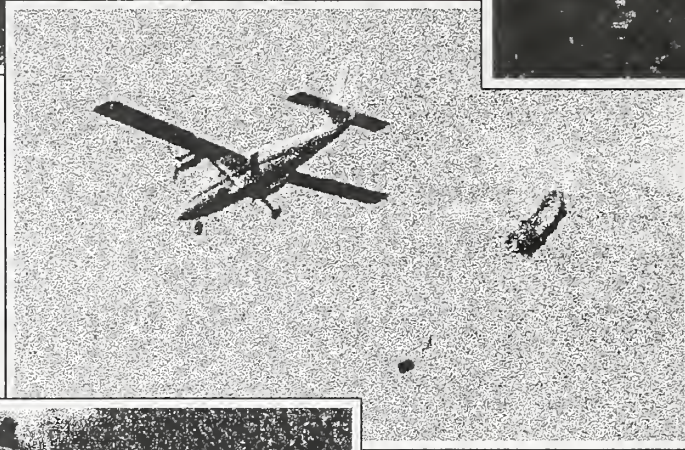
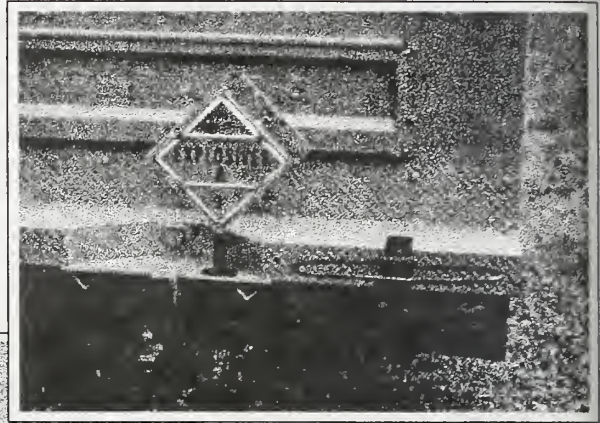
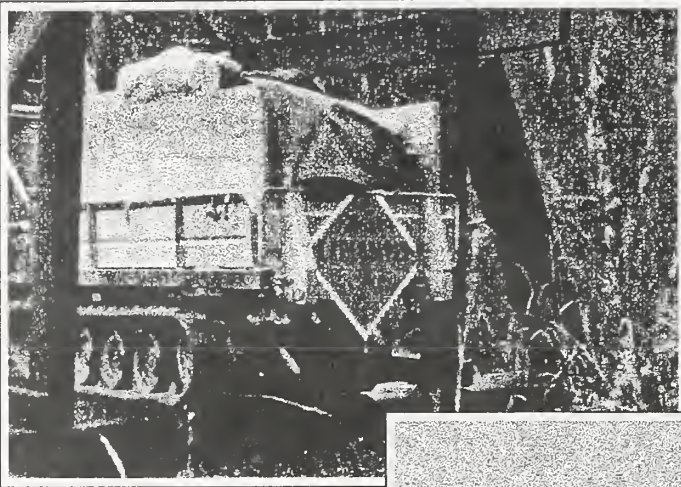
(4) These distances apply to blasting agents which pass the insensitivity test prescribed in regulations of the U.S. Department of Transportation (49 *CFR Part 173*).

(5) Earth or sand dikes, or enclosures filled with the prescribed minimum thickness of earth or sand are

acceptable artificial barricades. Natural barricades, such as hills or timber of sufficient density that the surrounding exposures which require protection cannot be seen from the “donor” when the trees are bare of leaves, are also acceptable.

(6) For determining the distances to be maintained from inhabited buildings, passenger railways, and public highways, use the table in § 55.218.

## Chapter 4



# Chapter 4—Transportation

## Section Contents

<b>4.1 General</b>	<b>39</b>
<b>4.2 Transporting Explosives By Motor Vehicle</b>	<b>39</b>
4.2.1 Operator Requirements	39
4.2.2 Vehicle Requirements	43
4.2.3 Loading/Unloading	44
4.2.4 Detonators	44
4.2.5 Safety	50
<b>4.3 Transporting Explosives With Pack Stock</b>	<b>52</b>
<b>4.4 Transporting Explosives With Trail Vehicles and ATV's</b>	<b>53</b>
<b>4.5 Transporting Explosives By Vessel</b>	<b>53</b>
<b>4.6 Transporting Explosives By Aircraft</b>	<b>53</b>

## 4.1 General

Explosives pose additional risk to health, safety, and property during transportation. Therefore, special requirements have been developed for transporting various types of explosives by motor vehicle, over water, by rail, and by aircraft.

In general, shipments of explosives will comply with the Code of Federal Regulations CFR 49 and State and local (municipal) laws. Other

regulations may also need to be addressed, such as those from the United States Coast Guard and port and harbor authorities.

## 4.2 Transporting Explosives By Motor Vehicle

### 4.2.1 Operator Requirements

Vehicle operators must hold a valid State commercial motor vehicle operator's license for the class of vehicle being operated, including any required hazardous materials endorsements. Vehicles transporting explosives shall be driven by drivers certified to transport explosives in accordance with **CFR 49, Part 383** and must be qualified operators as per **CFR 49, Part 391**.

The driver must be familiar with the traffic regulations and state laws governing the transportation of explosives. This certified individual must remain in or near the vehicle at all times.

When transporting explosives, a written document describing the type and quantity of explosives shall be in the vehicle and readily available.

When the driver is at the vehicle's controls, the documents shall be:

- a. In immediate reach while the driver is restrained by the lap belt; and
- b. Either readily visible to a person entering the driver's compartment or in a holder

mounted to the inside of the door on the driver's side of the vehicle.

When the driver is not at the vehicle's controls, the shipping paper shall be:

- a. In a holder mounted to the inside of the door on the driver's side of the vehicle; or
- b. On the driver's seat in the vehicle.

The following documents must be in possession of the driver:

- a. A document with instructions on what to do in the event of an accident or delay. The name of the explosive hauled and names and phone numbers of all persons (Chemtrec) to contact in the event of an accident must be on this document.
- b. Proper shipping papers for hazardous materials (Hazardous Materials Bill of Lading, see Figure 4-1).
- c. A written route plan for the transportation of explosives.
- d. Copy of **CFR 49 part 397**, transportation of hazardous materials; driving and parking rules, Federal Motor Carrier Safety Regulations (See pages 41-43).

## EXPLOSIVES — HAZARDOUS MATERIALS

**Bill of Lading**

If Danger of Fire — EVACUATE AREA — Chemtrec 1-800-424-9300

ACCIDENT — NOTIFYFatal - Call D.O.T. Portland, Oregon  
1-503-221-4902Other - Call Local Authorities

Date \_\_\_\_\_

Ship to: \_\_\_\_\_ Route Plan: \_\_\_\_\_


NO. PKGS.	TYPE PKG.	PROPER SHIPPING NAME	AND	HAZARD CLASS	IDENT. NO.	EXEMPT PERMIT	GROSS WEIGHT
	Bxs	HIGH EXPLOSIVE		CLASS A EXPLOSIVE			
	Bxs	PROPELLANT EXPLOSIVE, LIQUID		CLASS B EXPLOSIVE			
	Bxs	PROPELLANT EXPLOSIVE, SOLID		CLASS B EXPLOSIVE			
	Bxs	BLASTING CAPS		CLASS EXPLOSIVE			
	Bxs	BLASTING CAPS - ELECTRIC		CLASS EXPLOSIVE			
	Bxs	DETONATORS		CLASS EXPLOSIVE			
	Bxs	DETONATORS - ELECTRIC		CLASS EXPLOSIVE			
	Bxs	DETONATING PRIMER		CLASS EXPLOSIVE			
	Bxs	DETONATING CORD		CLASS EXPLOSIVE			
	Bxs	CORDEAU DETONANT FUSE		CLASS C EXPLOSIVE			
	Bxs	FUSE, SAFETY		CLASS C EXPLOSIVE			
	Bxs	IGNITER CORD		CLASS C EXPLOSIVE			
	Bxs	FUSE LIGHTER		CLASS C EXPLOSIVE			
	Bags	AMMONIUM NITRATE - FUEL OIL MIXTURE		BLASTING AGENT			
	Bags			BLASTING AGENT			
	Bags	AMMONIUM NITRATE FERTILIZER		OXIDIZER	UN2067		
					TOTAL WEIGHT		

This is to certify that the above named materials are properly classified, described, packaged, marked and labeled; and are in proper condition for transportation according to the applicable regulations for the Department of Transportation.

PLACARDS: — Supplied — Applied — A — B — DANGEROUS — NONE REQUIRED

(Circle as Required)

OXIDIZER, UN 2067 — BLASTING AGENT

SIGNATURE \_\_\_\_\_

Figure 4-1.—Sample hazardous materials bill of lading.

## CFR 49 Part 397

## Transportation of Hazardous Materials: Driving and Parking Rules

- Sec.
- 397.1 Application of the rules in this part.
  - 397.2 Compliance with Federal motor carrier safety regulations.
  - 397.3 State and local laws, ordinances, and regulations.
  - 397.5 Attendance and surveillance of motor vehicles.
  - 397.7 Parking.
  - 397.9 Routes.
  - 397.11 Fires.
  - 397.13 Smoking.
  - 397.15 Fueling.
  - 397.17 Tires.
  - 397.19 Instructions and documents.
  - 397.21 [Removed].

**AUTHORITY:** 18 U.S.C. 834, sec. 204 of the Interstate Commerce Act, as amended (49 U.S.C. 304), sec 6 of the Department of Transportation Act (49 U.S.C. 1655), and the delegation of authority by the Secretary of Transportation in 49 CFR 1.4(c), unless otherwise noted.

**§397.1 Application of the rules in this part.**

(a) Except as provided in paragraph (c) of this section, the rules in this part apply to each motor carrier engaged in the transportation of hazardous materials by a motor vehicle which must be marked or placarded in accordance with §177.823 of this title and to—

(a)(1) Each officer or employee of the carrier who performs supervisory duties related to the transportation of hazardous materials, and

(a)(2) Each person who operates or who is in charge of a motor vehicle containing hazardous materials.

(b) Each person designated in paragraph (a) of this section must know and obey the rules in this part.

(c) Intracity operations: The rules in this part do not apply to a driver or a vehicle wholly engaged in exempt intracity operations as defined in §390.16 of this chapter.

**§397.2 Compliance with federal motor carrier safety regulations.**

A motor carrier or other person to whom this part is applicable must comply with the rules in Part 390 through 397 inclusive of this subchapter when he is transporting hazardous materials by a motor vehicle which must be marked or placarded in accordance with §177.823 of this title.

**§397.3 State and local laws, ordinances and regulations.**

Every motor vehicle containing hazardous materials must be driven and parked in compliance with the laws, ordi-

nances, and regulations of the jurisdiction in which it is being operated, unless they are at variance with specific regulations of the Department of Transportation which are applicable to the operation of that vehicle and which impose a more stringent obligation or restraint.

**§397.5 Attendance and surveillance of motor vehicles.**

(a) Except as provided in paragraph (b) of this section, a motor vehicle which contains Class A or Class B explosives must be attended at all times by its driver or a qualified representative of the motor carrier that operates it.

(b) The rules in paragraph (a) of this section do not apply to a motor vehicle which contains Class A or Class B explosives if all the following conditions exist—

(b)(1) The vehicle is located on the property of a motor carrier on the property of a shipper or consignee of the explosives, in a safe haven, or, in the case of a vehicle containing 50 pounds or less of either Class A or Class B explosives, on a construction or survey site; and

(b)(2) The lawful bailee of the explosives is aware of the nature of the explosives the vehicle contains and has been instructed in the procedures he must follow in emergencies, and

(b)(3) The vehicle is within the bailee's unobstructed field of view, or is located in a safe haven.

(c) A motor vehicle which contains hazardous materials other than Class A or Class B explosives and which is located on a public street or highway or the shoulder of a public highway must be attended by its driver. However, the vehicle need not be attended while its driver is performing duties which are incident and necessary to his duties as the operator of the vehicle.

(d) For purposes of this section—

(d)(1) A motor vehicle is attended when the person in charge of the vehicle is on the vehicle, awake, and not in a sleeper berth, or is within 100 feet of the vehicle and has it within his unobstructed field of view.

(d)(2) A qualified representative of a motor carrier is a person who—

(i) Has been designated by the carrier to attend the vehicle;

(ii) Is aware of the nature of the hazardous materials contained in the vehicle he attends.

(iii) Has been instructed in the procedures he must follow in emergencies, and

(iv) Is authorized to move the vehicle and has the means and ability to do so.

(d)(3) A safe haven is an area specifically approved in writing by local, State, or Federal governmental authorities for the parking of unattended vehicles containing Class A or Class B explosives.

(e) The rules in this section do not relieve a driver from any obligation imposed by law relating to the placing of warning devices when a motor vehicle is stopped on a public street or highway.

**§397.7 Parking.**

(a) A motor vehicle which contains Class A or Class B explosives must not be parked under any of the following circumstances—

(a)(1) On or within 5 feet of the traveled portion of a public street or highway,

(a)(2) On private property (including premises of a fueling or eating facility) without the knowledge and consent of the person who is in charge of the property and who is aware of the nature of the hazardous materials the vehicle contains, or

(a)(3) Within 300 feet of a bridge, tunnel, dwelling, building, or place where people work, congregate, or assemble, except for brief periods when the necessities of operation require the vehicle to be parked and make it impracticable to park the vehicle in any other place.

(b) A motor vehicle which contains hazardous materials other than Class A or Class B explosives must not be parked on or within five feet of the traveled portion of public street or highway except for brief periods when the necessities of operation require the vehicle to be parked and make it impracticable to park the vehicle in any other place.

**§397.9 Routes.**

(a) Unless there is no practicable alternative, a motor vehicle which contains hazardous materials must be operated over routes, which do not go through or near heavily populated areas, places where crowds are assembled, tunnels, narrow streets, or alleys. Operating convenience is not a basis for determining whether it is practical to operate a motor vehicle in accordance with this paragraph. This paragraph does not apply to radioactive materials (see §177.825 of this title).

(b) Before a motor carrier requires or permits a motor vehicle containing Class A or Class B explosives to be operated, the carrier must prepare a written plan of a route that complies with the rules in paragraph (a) of this section for that vehicle and must furnish a copy of the written plan to the driver. However, the driver may prepare the written plan as agent for the motor carrier when the driver begins a trip at a location other than the carrier's terminal.

**§397.11 Fires.**

(a) A motor vehicle containing hazardous materials must not be operated near an open fire unless its driver has first taken precautions to ascertain that the vehicle can safely pass the fire without stopping.

(b) A motor vehicle containing hazardous materials must not be parked within 300 feet of an open fire.

**§397.13 Smoking.**

No person may smoke or carry a lighted cigarette, cigar, or pipe on or within 25 feet of—

(a) A motor vehicle which contains explosives, oxidizing materials, or flammable materials; or

(b) An empty tank motor vehicle which has been used to transport flammable liquids or gases and which, when so used, was required to be marked or placarded in accordance with the rules in §177.823 of this title.

**§397.16 Fueling.**

When a motor vehicle which contains hazardous materials is being fueled—

(a) Its engine must not be operating, and

(b) A person must be in control of the fueling process at the point where the fuel tank is filled.

**§397.17 Tires.**

(a) If a motor vehicle which contains hazardous materials is equipped with dual tires on any axle, its driver must stop the vehicle in a safe location at least once during each 2 hours or 100 miles of travel, whichever is less, and must examine its tires. The driver must also examine the vehicle's tires at the beginning of each trip and each time the vehicle is parked.

(b) If, as the result of an examination pursuant to paragraph (a) of this section, or otherwise, a tire is found to be flat leaking, or improperly inflated, the driver must cause the tire to be repaired, replaced, or properly inflated before the vehicle is driven. However, the vehicle may be driven to the nearest safe place to perform the required repair, replacement, or inflation.

(c) If, as the result of an examination pursuant to paragraph (a) of this section, or otherwise, a tire is found to be overheated, the driver shall immediately cause the overheated tire to be removed and placed at a safe distance from the vehicle. The driver shall not operate the vehicle until the cause of the overheating is corrected.

(d) Compliance with the rules in this section does not relieve a driver from the duty to comply with the rules in §§397.5 and 397.7.

**§397.19 Instructions and documents.**

(a) A motor carrier that transports Class A or Class B explosives must furnish the driver of each motor vehicle in which the explosives are transported with the following documents:

(a)(1) A copy of the rules in this part, and

(a)(2) [Reserved]

(a)(3) A document containing instructions on procedures to be followed in the event of accident or delay. The documents must include the names and telephone numbers of persons (including representatives of carriers or shippers) to be contacted, the nature of the explosives being transported, and the precautions to be taken in emergencies such as fires accidents, or leakages.

(b) A driver who receives documents in accordance with paragraph (a) of this section must sign a receipt for them. The carrier shall retain the receipt in his files for 1 year at his principal place of business. However, upon a written request to, and with the approval of, the Director, Regional Motor Carrier Safety Office, for the region in which a motor carrier has his principal place of business, the

carrier may maintain the receipts at a regional or terminal office. The addresses and jurisdictions of the Directors of Regional Motor Carrier Safety Offices are shown in §390.40 of this subchapter.

(c) A driver of a motor vehicle which contains Class A or Class B explosives must be in possession of, be familiar with and be in compliance with—

(c)(I) The documents specified in paragraph (a) of this section;

((c)2) The documents specified in §177.817 of Chapter I of this title; and

(c)(3) The written route plan specified in §397.9(b).

#### §397.21 [Removed]

## 4.2.2 Vehicle Requirements

### Condition

Thoroughly inspect all vehicles that transport explosives and correct all deficiencies before use. Vehicles, including engines, shall be clean, in good mechanical condition, and free of leaks. All safety equipment must be in good repair.

If vehicles do not have an enclosed bed, cover the bed with a flame and moisture-proof tarpaulin or other effective protection against moisture and sparks. All vehicles transporting explosives shall have tight floors. Cover any exposed spark-producing metal on the inside of the bed with wood or other non-sparking materials to prevent contact with explosive containers. Do not load explosives above the sides of an open-bed vehicle.

Secure any package containing explosives to prevent movement while vehicle is moving.

### Fire Extinguishers

Equip every motor vehicle used for transporting explosives with at least two 10-lb or higher rated fire extinguishers. Securely mount the extinguishers near the driver for

immediate access. Only extinguishers listed or approved by the Underwriter's Laboratories, or Factory Mutual Liability Insurance Co. of America are suitable for use on explosives-carrying vehicles. The rating is shown on the approved label.

### Gross Weight Capacity

Vehicles shall be strong enough to carry the load without exceeding rated weight capacity.

### Placarding

Placarding shall be in accordance with 49 CFR, (Part 172.500, Subpart F Placarding). Mark or placard vehicles transporting explosives on both sides, front and rear (Table 4-1). When mixed loads are transported, display the placard for the most hazardous explosive. Explosives placards shall be square on-point (diamond shape) and measure 10-3/4 inches on each side. The

Table 4-1.—Placarding requirements.

HAZARD CLASS	PLACARD
Class A Explosives	EXPLOSIVES A <sup>1</sup>
Class B Explosives	EXPLOSIVES B <sup>2</sup>
Poison A	POISON GAS <sup>1</sup>
Flammable Solid (Dangerous When Wet Label Only)	FLAMMABLE SOLID W <sup>3</sup>
Radioactive Material	RADIOACTIVE <sup>4,5</sup>
Radioactive Material: Uranium hexafluoride, fissile (containing 0.7 pct or less U <sup>235</sup> )	RADIOACTIVE <sup>4</sup> and CORROSIVE <sup>5</sup>
Radioactive Material: Uranium hexafluoride, low specific activity (containing 0.7 pct or less U <sup>235</sup> )	RADIOACTIVE <sup>4,5</sup> and CORROSIVE <sup>5</sup>

1. See sec. 172.510(a)

2. **EXPLOSIVES B** placard not required if the transport vehicle or freight container contains class A explosives and is placarded **EXPLOSIVES A** as required.

3. **FLAMMABLE SOLID "W"** placard is required only when the **DANGEROUS WHEN WET** label is specified in Sec. 172.101 for a material classed as a Flammable Solid.

4. Applies only to any quantity of packages bearing the **RADIOACTIVE** Yellow 111 label. (See Sec. 172.403)

5. For exclusive use shipments (See Sec. 173.403) of low specific activity radioactive materials transported in accordance with Sec. 173.425(b) or (c).

6. **CORROSIVE** placard not required for shipments of less than 1000 pounds gross weight.

placards shall be orange with a white border and the symbol and print shall be black.

The vehicle does not require placards when carrying blasting

caps (fuse-type or electric) in quantities of 1,000 or less, or just blasting agents or Class C explosives in quantities of 1,000 pounds or less (Table 4-2).

When carrying 1,000 pounds or less of unmixed components of explosives (two component), placards are not required.

Blasting agents in quantities greater than 1,000 pounds require "Blasting Agent" placards (Table 4-2).

Other explosive materials in any quantity such as dynamite, mixed component explosives, primers, fireline explosives, or avalanche ammunition require "Explosives A" placards (Table 4-1).

Blasting caps in quantities greater than 1,000 require "Explosives A" placards.

Table 4-2.—Placarding requirements.

HAZARD CLASS	PLACARD
Class C Explosives	DANGEROUS <sup>1,9</sup>
Blasting Agents	BLASTING AGENTS <sup>9,10</sup>
Nonflammable Gas	NONFLAMMABLE GAS <sup>9</sup>
Nonflammable Gas (Chlorine)	CHLORINE <sup>7</sup>
Nonflammable Gas (Fluorine)	POISON
Nonflammable Gas (Oxygen, cryogenic liquid)	OXYGEN
Flammable Gas	FLAMMABLE GAS <sup>8</sup>
Combustible Liquid	COMBUSTIBLE <sup>3,4</sup>
Flammable Liquid	FLAMMABLE
Flammable Solid	FLAMMABLE SOLID <sup>5</sup>
Oxidizer	OXIDIZER <sup>9,10</sup>
Organic Peroxide	ORGANIC PEROXIDE
Poison B	POISON
Corrosive Material	CORROSIVE <sup>6</sup>
Irritating Material	DANGEROUS

1. Applies only to a class C explosive required to be labeled with an **EXPLOSIVE C** label.

2. [Reserved]

3. **COMBUSTIBLE** placard required only when a material classed as a combustible liquid is transported in a packaging having a rated capacity of more than 110 gallons, a cargo tank, or a tank car.

4. A **FLAMMABLE** placard may be used on a cargo tank and a portable tank during transportation by highway and water and on a compartmented tank car containing materials classed as flammable liquid and combustible liquid.

5. Except when offered for transportation by water, a **FLAMMABLE** placard may be displayed in place of a **FLAMMABLE SOLID** placard except when a **DANGEROUS WHEN WET** label is specified for the material in Sec. 172.101 (See Table 4-1, this section.)

6. See Sec. 173.245(b) of this subchapter for authorized exceptions.

7. **CHLORINE** placard required only for a packaging having a rated capacity of more than 110 gallons; the **NONFLAMMABLE GAS** placard for packaging having a rated capacity of 110 gallons or less.

8. A **NONFLAMMABLE GAS** placard is not required on a motor vehicle displaying a **FLAMMABLE GAS** placard or an **OXYGEN** placard.

9. **BLASTING AGENTS**, **OXIDIZER** and **DANGEROUS** placards need not be displayed if a transport vehicle or freight container also contains Class A or B explosives and is placarded **EXPLOSIVES A** or **EXPLOSIVES B** as required.

10. Except for shipments by water, **OXIDIZER** placards need not be displayed if a freight container, motor vehicle, or rail car also contains blasting agents and is placarded **BLASTING AGENT** as required.

A transport vehicle or freight container containing two or more classes of materials requiring different placards specified in Table 4-2 may be placarded **DANGEROUS** in place of the separate placarding specified for each of those classes of material specified in Table 4-2. However, when 5,000 pounds or more of one class of materials is loaded therein at one loading facility, the placard specified for that class in Table 4-2 must be applied. This paragraph does not apply to a portable tank, cargo tank, or tank car.

When the gross weight of all hazardous materials covered by Table 4-2 is less than 1,000 pounds, no placard is required on a transport vehicle or freight container for the Table 4-2 materials. A Table 4-1 material must be placarded as specified in Table 4-1. This paragraph does not apply to portable tanks, cargo tanks, tank cars, transportation by air or water, or transport vehicles and freight containers subject to Sec. 172.505.

Each transport vehicle and freight container that contains a material subject to the "Poison-Inhalation Hazard" shipping paper description must be placarded "**POISON**" on each side and each end in addition to the placard required in Sec. 172.504. Duplication of the **POISON** placards is not required nor display of the UN class numbers at the bottom of additional placards required by this section.

### 4.2.3 Loading/Unloading

No explosives shall be loaded or unloaded from a vehicle with the engine running.

No bale hooks or other metal tools shall be used for the loading, unloading, or other handling of explosives. No package or other container of explosives, except barrels or kegs, shall be rolled. No packages of explosives shall be thrown or dropped during the process of loading, unloading, or handling. Special care shall be exercised to insure that packages or other containers containing explosives shall not catch fire from sparks or hot gases from the exhaust or tailpipe.

### 4.2.4 Detonators

Exploding Bridgewire Detonators (EBW's) contain no primary explosives and therefore may be transported with other explosives when packaged in the original

manufacturer's container (see 49 CFR, 173.113 and 49 CFR 177.848 (DOT)

Blasting caps, electric or fuse, contain a primary explosive and therefore may not be transported in the same vehicle with other

explosives, unless packed in wooden or fiberboard boxes as per 49 CFR 173.66 and 173.68, and CFR 177.835. Boxes are in turn loaded into portable containers or separate compartments that meet the requirements of the Institute of Makers of Explosives IME 22

Standard. When electric blasting caps are carried in a vehicle equipped with a two-way radio, the transmitter must be turned off when caps are placed into or removed from the portable container.

## CFR 49 Part 173.66 Detonators

### § 173.66 Detonators.

(a) Unless otherwise specified in this section, detonators must be packed in accordance with the following:

(a)(1) They must be snugly packed in strong inside packagings.

(a)(2) Inside packagings must be snugly packed in an outside packaging specified in paragraph (e) of this section.

(a)(3) For devices containing no more than 10 grams of explosive (excluding ignition and delay charges):

(i) *No more than 50 devices may be packed in one inside packaging;*

(ii) *No more than 500 devices may be packed in one outside packaging; and*

(iii) *The gross weight of the completed package may not exceed 150 pounds or the gross weight permitted by the specification for the outside packaging used, whichever is less.*

(b) Detonators that are blasting caps (including percussion activated) or delay connectors in metal tubes, must be packed as specified in paragraph (a) of this section. In addition:

(b)(1) They must be packed in inside packagings with the open ends of any device covered with an appropriate cushioning material;

(b)(2) Inside packagings must be snugly packed in intermediate packagings consisting of cartons, or wrappings made of paper, plastic, or pasteboard;

(b)(3) Intermediate packagings must be separated from the outside packaging by at least 1 inch of cushioning material; and

(b)(4) For devices containing no more than 3 grams of explosive (excluding ignition and delay charges):

(i) *No more than 110 devices may be packed in one inside packaging; and*

(ii) *No more than 5,000 devices may be packed in one outside packaging.*

(c) Detonators that are electric blasting caps, delay connectors in plastic sheaths, or blasting caps with empty

plastic tubing, must be packed as specified in paragraph (a) of this section, except that:

(c)(1) Devices containing no more than 3 grams of explosive (excluding ignition and delay charges) may be packed as follows:

(i) *No more than 100 devices may be packed in one inside packaging; and*

(ii) *No more than 1,000 devices may be packed in one outside packaging.*

(c)(2) Devices that are electric blasting caps with leg wires 4 feet long or longer, delay connectors in plastic sheaths, or blasting caps with empty plastic tubing 12 feet long or longer, and contain no more than 1 gram of explosive (excluding ignition and delay charges) may be offered for transportation and transported in an IME Standard 22 container or compartment without the outside packaging specified in paragraph (e)(1) or (e)(2) of this section if:

(i) *The devices are packed as specified in paragraph (a)(1) and (a)(3)(i) of this section;*

(ii) *There are no more than 1000 detonators in the IME Standard 22 container or compartment; and*

(iii) *No material is loaded on top of the IME Standard 22 container, or no material is loaded against the outside of the door of the IME Standard 22 compartment.*

(c)(3) Inside packaging is not required for electric blasting caps when packed in inside pasteboard tubes, or when their leg wires are wound on spools with the caps either placed inside the spool or securely taped to the wire on the spool, so as to restrict freedom of movement of the caps and to protect them from impact forces.

(d) Detonators that are blasting caps with safety fuse, blasting caps with metal clad mild detonating cord, blasting caps with detonating cord, or blasting caps with shock tubes, must be packed in accordance with the requirements of paragraph (a) of this section, except that:

(d)(1) The blasting caps are not required to be attached to the safety fuse, metal clad mild detonating cord, detonating cord, or shock tube; and

(d)(2) Inside packagings are not required if the packing configuration restricts freedom of movement of the caps and protects them from impact forces.

(e) Detonators with or without inside packaging as provided for in paragraphs (a) through (d) of this section, must be packed in the following outside packagings.

(e)(1) **Specification 14, 15A, 16A, or 19B §§ 178.165, 178.168, 178.185, 178.191 of this subchapter.** Wooden boxes.

(e)(2) **DOT Specification 12H, 23F, or 23H §§ 178.209, 178.214, 178.219 of this subchapter** fiberboard box.

(e)(3) IME Standard 22 container or compartment when the detonators conform with conditions and limitations specified in paragraph (c)(2) of this section.

(f) Each outside packaging containing detonators must be plainly marked "DETONATORS—HANDLE CAREFULLY"

and bear the appropriate explosives label specified in §172.411 of this subchapter.

(g) Devices subject to this section and approved by an agency listed in §173.86(b) before January 1, 1980, may be transported subject to conditions of the approval and in accordance with regulations in effect on October 31, 1979, until December 31, 1985. Applicability of this paragraph is further limited to detonators packaged for transportation prior to January 1, 1985.

[Amdt. 173-134, 44 FR 70730, Dec. 10, 1979, as amended by Amdt. 173-149, 46 FR 49892, Oct. 8, 1981; Amdt. 173-182, 50 FR 804, Jan. 7, 1985]

## Standard For The Safe Transportation of Class C Detonators (Blasting Caps) In A Vehicle With Certain Other Explosives.

*IME Safety Library Publications No. 22*

### I. General

Class C detonators (blasting caps) and Class A or Class B explosives may be transported together on a vehicle using IME containers or compartments under the following conditions:

#### A. Products

1. *As used in this standard, Class C detonators (blasting caps) include detonators approved for transportation as Class C explosives by the U.S. Department of Transportation (DOT).*
2. *As used in this standard, Class A or Class B explosives include all materials so described by regulation of the U.S. Department of Transportation in 49 CFR Part 173. As used, Class A or Class B explosives do not include initiating explosives (e.g.: Class A detonators) and any explosives forbidden by the U.S. Department of Transportation in 49 CFR, Sections 171.101 and 173.51.*

#### B. IME Containers or Compartments

1. *A portable IME container placed within and readily removable from the cargo-carrying space of the vehicle.*
2. *An IME container securely attached:*
  - a. *Above the cab of the vehicle (Figure 4-2).*
  - b. *To the vehicle frame under the cargo space (Figure 4-3).*
3. *A built-in IME compartment in the cargo space of the vehicle (Figure 4-4).*

Note: The configuration shown in this figure is equally applicable to multi-axle and "cab-over" vehicles.

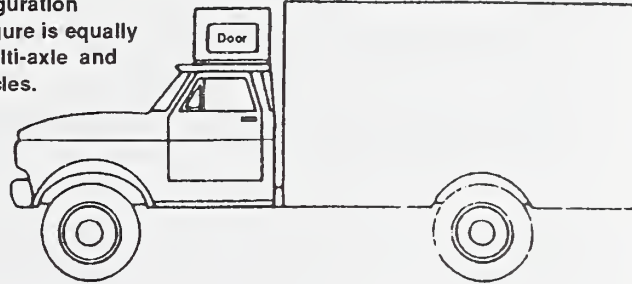


Figure 4-2.—IME container above the cab.

Note: The configuration shown in this figure is equally applicable to multi-axle and "cab-over" vehicles.

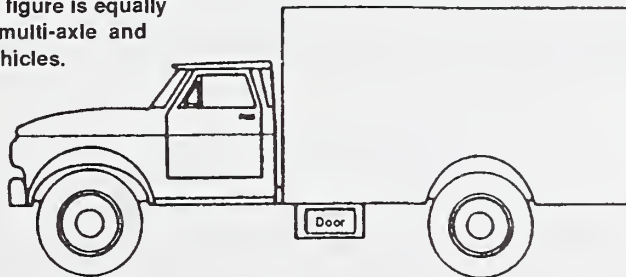
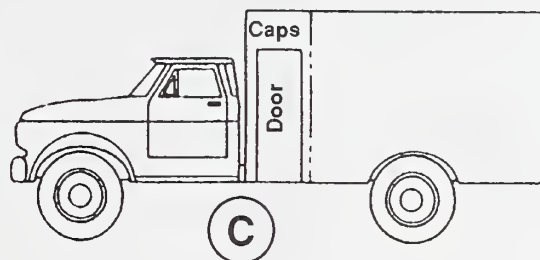
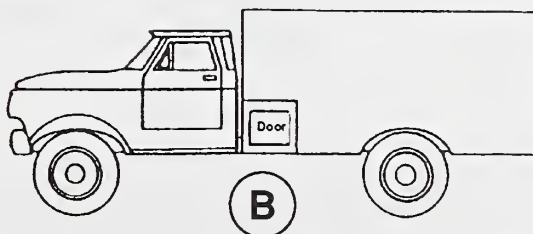
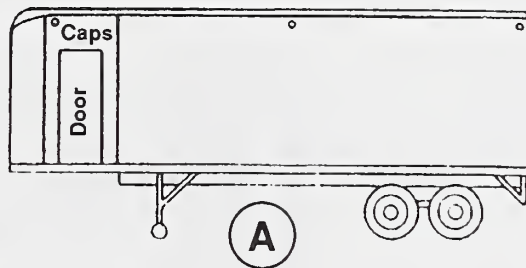


Figure 4-3.—IME container under truck body.



Note: The configurations shown in Figures B & C are equally applicable to multi-axle and "cab-over" vehicles.

Figure 4-4.—Examples of other IME containers.

C. Packaging, Labeling and Marking

1. Packaging must be in accordance with the hazardous materials regulations (CFR 49 Part 397) of the U.S. Department of Transportation.
2. Notwithstanding 1 above, 1,000 or less Class C detonators (blasting caps) may be transported in an IME container when packaged in cartons or tubes only as specified in 49 CFR, Section 173.66 without a DOT specification outside container.
3. When an IME container that is an integral part of the vehicle body, or is permanently attached to a motor vehicle, is used to transport Class C detonators (blasting caps) in cartons or tubes only as authorized in 2 above, and the vehicle contains any quantity of Class A or Class B explosives and is placarded accordingly, labeling and markings of the IME container holding the Class C detonators (blasting caps) is not required.

D. Use of IME Container or Compartment

1. In the combined transportation of Class C detonators (blasting caps and Class A or Class B explosives either the Class C detonators (blasting caps) or the Class A or Class B explosives may be transported in the IME container or compartment.

## I. Construction

The IME container or compartment construction detail is shown in Figures 4-5 and 4-6. A means to release the pressure developed by accidental detonation of the contents without allowing debris to escape has been provided through the venting procedure outlined in paragraph J.1 below. No other changes in the construction specifications or materials are authorized.

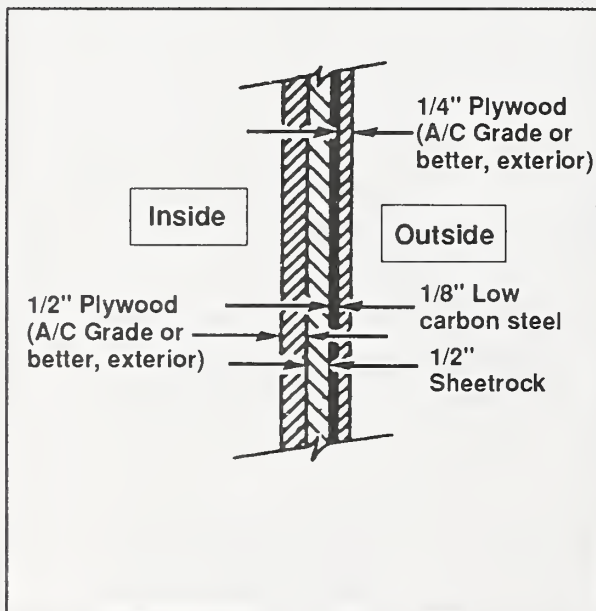


Figure 4-5.—IME container construction.

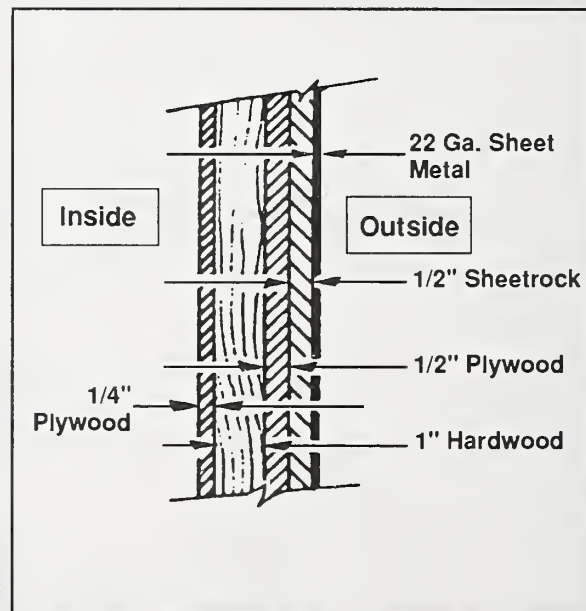


Figure 4-6.—IME container construction.

- A. The IME container or compartment must provide for total enclosure of the contents.
- B. The top, lid or door, sides and bottom of each IME container or compartment must be of laminate construction consisting of A/C grade or better exterior plywood, sheetrock and low-carbon steel. In order of arrangement, from inside to outside the laminate must consist of the following with minimum thickness of each lamination as indicated: 1/2-inch plywood, 1/2-inch sheetrock, 1/8-inch low-carbon steel, and 1/2-inch plywood with the 1/4-inch plywood to the exterior of the IME container or compartment. See Figure 4-5 for details of laminate construction.
- C. The laminated materials must be securely bound together by waterproof adhesive or other equally effective means.
- D. The steel at the joints of laminations must be secured by continuous fillet welds.
- E. The interior surfaces of the IME container or compartment must be constructed so as to prevent contact of contents with any sparking metal.
- F. There must be direct access to the IME container or into an IME compartment from outside the vehicle.
- G. Each IME container or compartment must have a snug-fitting continuous piano-type hinged lid or door and be equipped with a locking device.
- H. Without permitting direct access to contents under normal conditions, the locking or hinging mechanisms must permit at least one edge of the lid or door to rise or move outward at least 1/2-inch when subjected to internal pressure.
- I. The exterior of the IME container or compartment must be weather-resistant.
- J. As an alternative to the construction requirements shown in paragraph B above, an IME container for use only as illustrated in Figures 4-5 and 4-6 may be constructed as follows:
  1. *The top, lid or door, sides and bottom of each IME container must be of laminate construction consisting of A/C grade or better exterior plywood, solid hardwood, or sheetrock and sheet metal. In order of arrangement, from inside to outside, the laminate must consist of the following with the minimum thickness of each lamination as indicated: 1/4-inch plywood, 1-inch solid hardwood, 1/2-inch plywood, 1/2-inch sheetrock, and 22-gauge sheet metal constructed inside to outside in that order. See Figure 4-6 for details of laminate construction.*
  2. *The hardwood must be fastened together with wood screws, the 1/2-inch plywood must be fastened to the hardwood with wood screws, the inner 1/2-inch plywood must be fastened to the hardwood with adhesive and the 22-gauge sheet metal must be attached to the exterior of the IME container with screws.*

## 4.2.5 Safety

### Trailers

Do not haul explosives in small single axle utility trailers. If a trailer is required for equipment, attach with a positive grounding system. Use a trailer only when needed for the job, i.e., compressor, tools, etc.

Class A explosives may not be loaded into or carried on any vehicles if:

- a. More than two cargo-carrying vehicles are in the combination;
- b. Any full trailer in the combination has a wheel base of less than 184 inches;
- c. The other vehicle in the combination contains any initiating explosive.

### Repair

Do not take motor vehicles carrying explosives, blasting agents, or blasting supplies inside a garage or shop for repairs or servicing.

### Emergencies

In the event of breakdown or collision, secure the area and promptly notify the local fire and police departments for assistance.

Except in an emergency, do not park any vehicle transporting explosives, even though attended, on any public street adjacent to or in proximity to any bridge, tunnel, dwelling, building, or place where people work or assemble.

### Attendance and Surveillance of Motor Vehicles.

- a. Except as provided in paragraph (b) of this section, a

motor vehicle which contains Class A or Class B explosives must be attended at all times by its driver or a qualified representative of the motor carrier that operates it.

b. The rules in paragraph (a) of this section do not apply to a motor vehicle which contains Class A or Class B explosives if all of the following conditions exist:

1. The vehicle is located on the property of a motor carrier, on the property of a shipper or consignee of the explosives, in a safe haven, or, in the case of a vehicle containing 50 pounds or less of either Class A or Class B explosives, on a construction or survey site; and

2. The lawful bailee\* of the explosives is aware of the nature of the explosives the vehicle contains and has been instructed in the procedures he or she must follow in emergencies; and

3. The vehicle is within the bailee's\* unobstructed field of view or is located in a safe haven.

*\* Bailee is one who has custody of explosives.*

c. For purposes of this section:

1. A motor vehicle is attended when the person in charge of the vehicle is on the vehicle, awake and not in a sleeper berth, or is within 100 feet of the vehicle and has it within his or her unobstructed field of view.

2. A qualified representative of a motor carrier is a person who:

- (a). *Has been designated by the carrier to attend the vehicle;*

- (b). *Is aware of the nature of the hazardous materials contained in the vehicle he or she attends;*

- (c). *Has been instructed in the procedures to be followed in emergencies; and*

- (d). *Is authorized to move the vehicle and has the means and ability to do so.*

3. A safe haven is an area specifically approved in writing by local, state, or federal governmental authorities for the parking of unattended vehicles containing Class A or Class B explosives.

- d. The rules in this section do not relieve a driver from any obligation imposed by law relating to the placing of warning devices when a motor vehicle is stopped on a public street or highway.

### Parking

a. A motor vehicle which contains Class A or Class B explosives must not be parked:

1. On or within 5 feet of the traveled portion of a public street or highway;

2. On private property (including premises of a fueling or eating facility) without the knowledge and consent of the person who is in charge of the property and who is aware of the nature of the hazardous materials the vehicle contains; or

3. Within 300 feet of a bridge, tunnel, dwelling, building, or place where people work, congregate, or assemble, except for brief periods when the necessities of operation require the vehicle to be parked

and make it impracticable to park the vehicle in any other place.

## Routing and Scheduling

a. Unless there is no practical alternative, a motor vehicle which contains hazardous materials must be operated over routes which do not go through or near heavily populated areas, places where crowds are assembled, tunnels, narrow streets, or alleys. Operating convenience is not a basis for determining whether it is practical to operate a motor vehicle in accordance with this paragraph.

Plan routes and schedules to avoid densely populated areas, heavy traffic, adverse road and weather conditions, and night driving. Where present, follow designated routes established by local authorities through congested area.

## Railroad Grade Crossing

Any placarded vehicle, or one carrying any amount of chlorine, must stop at railroad crossings.

Stops must be made within 50 feet of the crossing, but no closer than 15 feet. When it is safe to cross the tracks, do so; do not shift gears while on the tracks.

Stops need not be made at:

- a. streetcar crossings or industrial switching tracks within municipalities.
- b. crossings where a police officer or flagman is directing traffic.
- c. crossings which are marked by a stop-and-go traffic light which is green.

d. abandoned rail lines and industrial or spur line crossings clearly marked "exempt".

## Accidents, Explosives

In the event of an accident involving any motor vehicle transporting any explosives, every available means shall be employed to prevent individuals, other than those employed in the protection of persons or property or in the removal of hazards or wreckage, from congregating in the vicinity: such means shall also be employed to prevent smoking, to keep flame away, and to safeguard against the aggravation of the hazard present, and to warn other users of the highway. In the event that any motor vehicle laden with or carrying dangerous explosives is entangled with another or with any other object or structure following an accident, no attempt shall be made to disentangle either vehicle or the laden vehicle from the object or structure until the lading, together with any fragments thereof, be removed to a place at least 200 feet from the vehicle (and preferably 200 feet from any habitation). In the event of fire involving a motor vehicle laden with any explosive, every practical effort shall be made to give warning of danger of explosion to habitants in the vicinity and to other users of the highway.

## Emergency Signals (Stopped Vehicles)

### a. Turn signals

Whenever a motor vehicle is stopped upon the traveled portion of a highway or the shoulder of a highway for any cause other than necessary traffic stops, the driver of the stopped vehicle shall immediately flash the two front and

two rear turn signals simultaneously as a vehicular traffic hazard warning and continue the flashing until warning devices are placed. The flashing signals shall be used during the time the warning devices are picked up for storage before moving of the vehicle. The flashing lights may be used at other times while a vehicle is stopped in addition to, but not in lieu of, the warning devices required by paragraph b(1) of this section.

### b. Placement of Warning Devices

**1. General Rule.** Except as provided in paragraph b(2) of this section, whenever a vehicle is stopped upon the traveled portion of a highway or the shoulder of a highway for any cause other than necessary traffic stops, the driver shall as soon as possible, but in any event within 20 minutes, place warning devices carried in the vehicle—either three emergency reflective triangles, three electric emergency lanterns, or three red emergency reflectors in the following manner:

- (a). *One at the traffic side of the stopped vehicle, within 20 feet of the front or rear of the vehicle;*
- (b). *One at a distance of approximately 100 feet from the stopped vehicle in the center of the traffic lane or shoulder occupied by the vehicle and in a direction toward traffic approaching in that lane; and*
- (c). *One at a distance of approximately 200 feet from the stopped vehicle in the center of the traffic lane or shoulder occupied by the*

*vehicle and in the direction in which traffic in that lane is moving.*

**2. Special Rules.** Business or residential districts. The placement of warning devices is not required within the business or residential district of a municipality, except during the time lighted lamps are required and when street or highway lighting is insufficient to make a vehicle clearly discernible at a distance of 500 feet to persons on the highway.

*Hills, curves, and obstructions.* If a motor vehicle is stopped within 500 feet of a curve, crest of a hill, or other obstruction to view, the driver shall place the warning signal required by paragraph b(1) of this section in the direction of the obstruction to view by a distance of 100 feet to 500 feet from the stopped vehicle so as to afford ample warning to other users of the highway.

*Divided or one-way roads.* If a motor vehicle is stopped upon the traveled portion or the shoulder of a divided or one-way highway, the driver shall place the warning devices required by paragraph b(1) of this section, one warning device at a distance of 200 feet and one warning device at a distance of 100 feet in a direction toward approaching traffic in the center of the lane or shoulder occupied by the vehicle. The driver shall place one warning device at the traffic side of the vehicle within 10 feet of the rear of the vehicle.

**3. Emergency Signals: Flame-Producing.** No driver shall attach or permit any person to attach a lighted fuse or other flame-producing emergency

signal to any part of a motor vehicle transporting explosives.

**4. Emergency Signals: Dangerous cargoes.** No driver shall use or permit the use of any flame-producing emergency signal for protecting any motor vehicle transporting explosives, Class A or Class B.

**5. Flame producing Devices Prohibited On Vehicles.** Liquid burning emergency flares, fusees, oil lanterns, or any signal produced by a flame shall not be carried on any motor vehicle transporting explosives, Class A or Class B.

## Delivery

Deliver explosives only to authorized persons and into approved magazines or approved temporary storage or handling areas. Do not park vehicle closer than 300 feet to buildings, bridges, tunnels, personnel, etc.

## Other Safety Measures

Never smoke within 100 feet of a motor vehicle transporting explosives. Do not drive, load, or unload the vehicle in a careless or reckless manner.

Unless state laws are more restrictive, two persons are permitted to ride in a vehicle transporting explosives.

## 4.3 Transporting Explosives With Pack Stock

Stock may carry explosives in remote areas with these restrictions:

a. Animals must be in good physical condition, well-shod, well trained for pack use, gentle, free of bad habits, and have been worked recently.

b. Handlers shall be experienced in handling stock and be either certified or accompanied by a person certified for transporting and storing explosives.

c. Pack saddles, ropes, and other equipment must be inspected and in good condition.

d. Detonators and explosives must be packed on separate animals just before departure.

e. Detonators must be packed in original containers with voids filled and well-wrapped and padded with nonmetallic articles, such as bed rolls and tents.

f. Explosives must be packed in original cases and covered with a flame-proof and moisture-proof tarpaulin. Experienced packers must tie up bundles and rope them to pack saddles.

g. Travel one-half hour after sunrise to one-half hour before sunset.

h. Use of drugs or alcohol is prohibited.

i. In lightning or storms, unload pack animals if time permits and move the string a safe distance away. If there is not time to unload, securely tether the pack animals carrying explosives and move the remaining string a safe distance away.

j. Consult tables 5.1 through 5.5, page 65 for the minimum distance a radio can be operated from the pack string.

No placards are required for a pack string carrying explosives.

## 4.4 Transporting Explosives With Trail Vehicles and ATV's

Motorized cargo carriers and ATV's may be used on limited jobs to move explosives in remote areas. Observe these restrictions:

- a. Never transport impact sensitive explosives with a two-wheel vehicle.
- b. Thoroughly inspect all carriers and ATV's and correct deficiencies before use. Carriers and ATV's including engines, must be clean and in good mechanical condition.
- c. Equip all carriers and ATV's with approved spark arrester and one pressure-type dry powder or carbon dioxide fire extinguisher, rated 2-BC or better.
- d. Do not exceed manufacturer's recommended load rating. In no case shall the weight of explosives exceed 200 pounds.
- e. Never transport detonators in the same cargo carrier or ATV with other explosives.
- f. Use operators experienced in operating cargo carriers or ATV's. Operators must be certified to transport and store explosives or be accompanied by someone who is.
- g. When loads include other equipment, tools, and supplies, limit explosives to no more than 50 pounds. When transporting such mixed cargo, pack the explosive in a metal box with a minimum 1/2-inch sponge rubber lining, hinged lid, and hasp. Fill all voids in the box. Paint the box red and stencil the word "Explosive" on top in 2-inch high white letters. Secure the box

to the bottom of the cargo deck or cargo rack away from the engine.

- h. Travel only between one-half hour after sunrise to one-half hour before sunset.
- i. Use of drugs or alcohol is prohibited while transporting explosives.
- j. Park the cargo carrier or ATV during lightning or storms; move all personnel a safe distance away.
- k. Consult tables 5.1 through 5.5, page 65 for the minimum distance a radio can be operated from a cargo carrier with explosives.
- l. Post explosives placards scaled to the space available on the carrier or ATV.

## 4.5 Transporting Explosives By Vessel

**Regulations.** Shipments of explosives and other dangerous articles aboard vessels (including lighters and barges) by commercial service shall conform to the regulations prescribed by the **Department of Transportation and Code of Federal Regulations (CFR) Title 49 Part 176 and CFR 46 and Bureau of Explosives Tariff 6000 series.**

- a. On any boat:
  - 1. Explosives must be placed upon a wooden platform.
  - 2. All Blasting caps and detonators must be carried on deck as far forward as possible, in their original cartons, in a watertight-wood-lined steel portable cap magazine.

3. If small boats are involved, carry the explosives on one, the caps on the other. Or if transporting the explosives to a destination where they will be unloaded such as a barge, make one trip with the explosives, and a second trip carrying the caps.

4. Situate explosives away from loading booms or hoists, where they will not be exposed to falling objects. Keep them isolated from potential sources of static-electricity, heat, and radio frequency energy.

5. A boat carrying explosives must fly the "Bravo" flag at the bow, however, since this is not likely to be understood by many boaters, "Explosives" signs should also be used in congested waters.

## 4.6 Transporting Explosives By Aircraft

**Caution:** The following information applies only to field operations such as fire operations or projects, avalanche control, or special projects approved by the Forest Service. It does not apply to commercial aircraft operation, e.g., any commercial airline under charter transporting fire personnel. For these types of operations, all the requirements of 49 CFR part 175 must be complied with.

Explosive materials can be transported by aircraft when the following conditions are met:

- a. All explosives must be prepared and packaged under the supervision of a certified blaster and

transported in undamaged original shipping containers. A shipper's declaration for dangerous goods must be completed (Figure 4-7).

**b.** High explosives must not be transported in the same container as detonators and must be separated from detonating materials. Detonating materials and explosives will be carried on different flights whenever possible and practical.

**c.** For separation purposes, exploding bridgewire detonators (EBWs) may be carried inside aircraft while explosive materials are transported by internal or external load, provided the detonators are contained in the original manufacturers package or packaged in an IME container. Electric blasting caps (EBCs), Nonel, and crimp caps must be packaged in an IME container and kept as far from the explosives as practical.

**d.** Explosives that will react with oil, flames, acids, storage batteries, oxidizing or corrosive compounds will not be transported on the same flight with the reacting materials unless separation of the materials can be achieved to prevent possibility of contact between such materials.

**e.** Explosives and detonators transported in the aircraft or on external cargo racks must be stowed separately, secured by tiedown straps, and be accessible for jettisoning whenever possible and practical.

**f.** No passengers other than those absolutely necessary for the completion of the mission involving the transport or use of explosives will be allowed on a flight transporting explosive materials.

**g.** All explosives, ammunition, and detonating materials must be transported under the control or direction of a qualified or certified person.

**h.** Flights transporting high explosives or detonating materials, will not be conducted over densely populated areas or in congested airways. During the approach and landing phase, the aircraft operator shall request appropriate vectors when under radar control to avoid heavily populated areas. Wherever Class A or B explosives are transported and a danger exists to people on the surface, advance permission from the owner or operator of any manned airport used must be obtained (See Figure 4-8).

**i.** Thermite grenades will remain in the original outside shipping containers while in transit. Any unused thermite grenade that has been removed from its inside sealed canister will be returned to the inside canister, repacked and closed in the original outside shipping container prior to loading aboard the aircraft.

**j.** No aerial dispensing of an explosive device will be conducted unless the dispensing method and/or dispensing device has been approved and accepted by the Forest Service (See **n. below**).

**k.** The pilot shall assure that no smoking, or the use of any open flame or spark-producing device, will be allowed while transporting explosives, ammunition, or initiating devices.

**l.** All packages containing explosives must be labeled on the outside of the package with the appropriate Hazardous Materials warning label.

**m.** In fire operations, only those explosives approved for use as a fireline explosive will be loaded on aircraft. In special operations, only the less sensitive explosives will be loaded on aircraft (i.e., water gels, emulsions, two-component, det cord).

**n.** When dynamite and blasting caps are carried for avalanche control

flights, the explosives must be handled and, at all times, be under the control of the blaster who is licensed under appropriate authority identified in writing to the FAA Civil Aviation Security Office responsible for the operator's overall aviation security program or the FAA Civil Aviation Security Office in the region where the operator is located.

**o.** Any aircraft carrying explosives and making a forced landing for minor repairs will not unload its cargo, but will be repaired at a safe distance in accordance with the quantity-distance requirements listed in Chapter 3. Any aircraft forced down for major repairs will be stored at a safe distance in accordance with the applicable quantity-distance tables.

**p.** Any aircraft carrying explosives making a landing for refueling purposes will not unload its cargo, but will be refueled in accordance with the quantity-distance requirements (see Chapter 3).

**q.** Prior to takeoff or landing of an aircraft loaded with explosives, the pilot will, in requesting the airdrome control tower for taxiing, takeoff, and/or parking instructions, notify the control tower as to the contents of the aircraft and request special consideration and priority be given the aircraft in landing, takeoff and/or parking.

**r.** The quantity-distance tables will be observed in parking aircraft loaded with ammunition and explosives and such aircraft will be adequately guarded.

**s.** Explosive placards will be displayed when an aircraft loaded with explosives is parked and during all loading and unloading operations. Appropriate fire symbols shall be placed alongside the placards at all airfields.

Figure 4-7.—Sample shipper's declaration for dangerous goods.

## Operating Authority For Aircraft Carrying Explosives

Approval to operate aircraft carrying explosives must be obtained in advance from airport authorities under provisions of 49 CFR 1/5.320.

Authority to operate at \_\_\_\_\_ Airport has been obtained  
from \_\_\_\_\_ who is \_\_\_\_\_ by telephone restrictions  
apply to operation at this airport:

Approach and Departure Routes \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

Landing and Take Off \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

Parking/Refueling \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

Loading and /or Unloading \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

-----  
By USFS or BLM Officer

Signed \_\_\_\_\_ Title \_\_\_\_\_

Time \_\_\_\_\_ Date \_\_\_\_\_

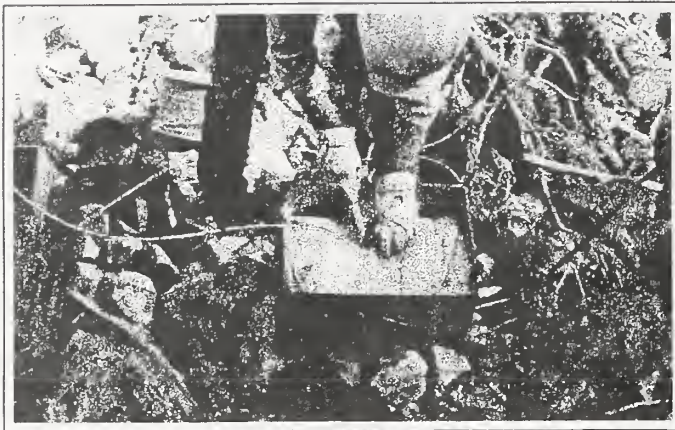
I hereby certify that the contents of this shipment are fully and accurately described above by proper shipping name and are classified, packed, marked, and labeled, and in proper condition for carriage by air according to applicable Department of Transportation Regulations. This shipment is within the limitations prescribed for cargo only aircraft.

Figure 4-8.—Operating Authority For Aircraft Carrying Explosives.

---

---

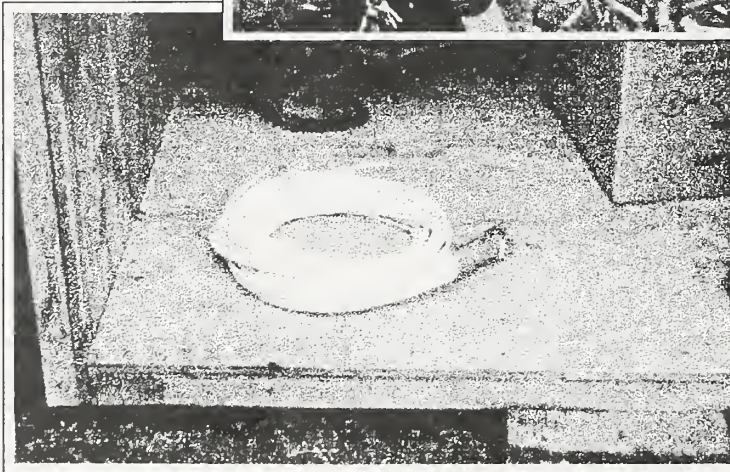
Notes:



**END  
BLASTING  
ZONE**



**TURN OFF  
2-WAY  
RADIO**



**BLASTING  
ZONE  
1000 FT**

Section Contents

5.1 Signing 59

5.2 Initiation 60

5.2.1 Electric Blasting Caps 60

5.2.2 Primers 60

5.2.3 Exploding Bridge-wire Detonators's (EBW's) 61

5.2.4 Detonating Cord 62

5.2.5 Drilling 63

5.2.6 Loading 63

5.2.7 Wiring 64

5.2.8 Firing 64

5.2.9 Static Electricity 66

5.2.10 Post Blast Procedures 66

5.3 Misfires 66

5.4 Disposing of Deteriorated or Damaged Explosives 67

5.4.1 General 67

5.4.2 Dynamite 67

5.4.3 Other Explosives 67

5.4.4 Detonators 68

5.4.5 Detonating Cord 68

5.4.6 Ammunition 68

5.5 Blast Design 68

5.5.1 Rules of Thumb for Blast Design 68

5.5.2 Rules of Thumb for Blasting Geometry 70

5.5.3 The Unified Rock Classification System and Determination of VOS 71

5.5.4 Characteristic Impedance Z 72

5.5.5 Kilobars of Detonation

Pressure K 72

5.5.6 Characteristic Powder Factor (CPF) 72

5.5.7 Examples for Estimating Blasting Projects 73

5.6 Ground Vibration and Airblast 75

5.1 Signing

The Blaster-In-Charge is responsible for posting flagers or guards and

warning signs, notifying all persons in the blast area, and giving all necessary audible warning signals.

All signing must conform to the *Manual of Uniform Traffic Control Devices* for streets and highways whenever blasting operations are conducted on any road or trail. The "Blasting Zone 1,000-foot" sign is intended for use in advance of any point or work site where there are explosives being used (Figure 5-1a). The "Turn Off 2-Way-Radio" sign and "End Blasting Zone" sign must be used in sequence with this sign (Figure 5-1b). Provisions shall be made for covering or removing the sign sequence when there are no explosives in the area or the area is otherwise secured.

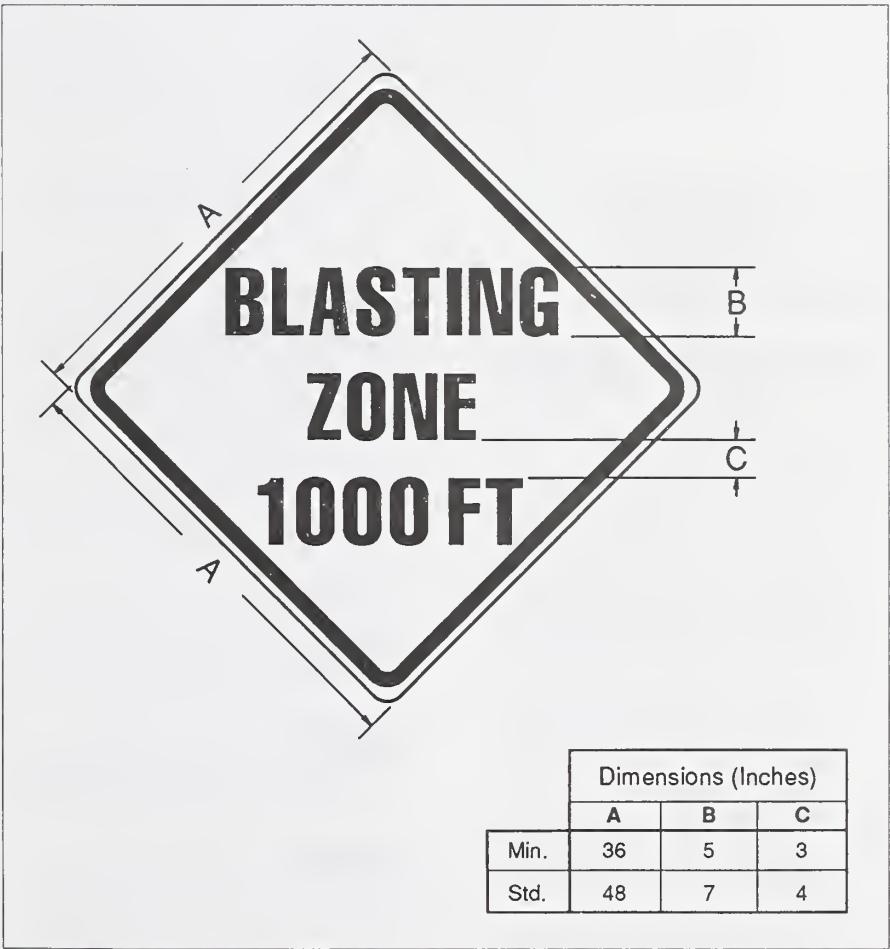
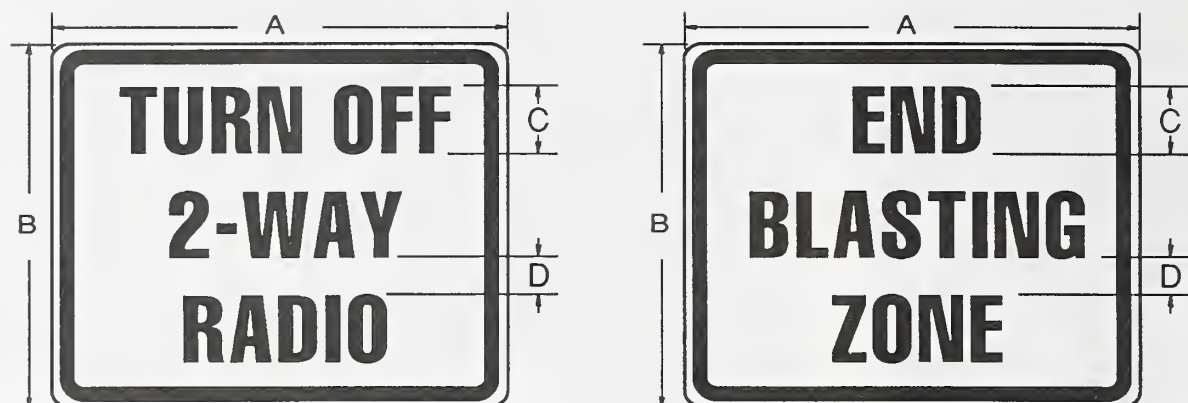


Figure 5-1a.—Blasting zone sign.



Dimensions (Inches)				
	A	B	C	D
Min.	36	30	5	3-1/8
Std.	42	36	7	3

Dimensions (Inches)				
	A	B	C	D
Min.	36	30	5	3-1/8
Std.	42	36	7	3

Figure 5-1b.—Blasting signs.

## 5.2 Initiation

### 5.2.1 Electric Blasting Caps

The blaster-in-charge must conduct a thorough survey for stray currents and eliminate any dangerous currents before adopting any system of electric firing with electric blasting caps and before loading any holes.

- Keep shunt on detonators until ready to connect them in series.
- Use only detonators of the same manufacture in the same circuit.
- Use only delays or instant detonators in a series. Do not mix.

Make up primers in accordance with methods outlined in the Institute of Makers of Explosives Publication NO. 17, *Safety in the transportation, Storage, Handling, and Use of Explosives*.

### 5.2.2 Primers

#### General

**Never** prepare more primers than immediately needed.

**Never** prepare primers in a magazine or near large quantities of explosive materials.

**Never** slit, drop, twist, or tamp a primer.

#### Preparing A Primer

**Always** insert the detonator completely into a hole in the explosive material made with a non-sparking punch designed for that purpose, or in the cap well of a manufactured booster.

**Always** secure the detonator within the primer.

**Always** point the detonator in the direction of the main explosive charge.

**Always** secure the detonator to a primer cartridge so that no tension is placed on the cap wires, safety fuses, plastic tubing, or detonating cord at the point of entry into the detonator.

**Never** use a cast primer or booster if the hole for the detonator is too small.

**Never** enlarge a hole in a cast primer or booster to accept a detonator.

**Never** punch explosive material that is very hard or frozen.

**Never** force a detonator into explosive material.

### Making Primers With Electric Detonators

Small Diameter Cartridges (less than 4 inches in diameter) (Figure 5-2):

**Step 1:** Punch a hole straight into one end of cartridge.

**Step 2:** Insert the detonator into the hole.

**Step 3:** Tie leg wires around the cartridge using a half-hitch.

**Never** pull the wires too tightly. This may break them or damage the insulation.

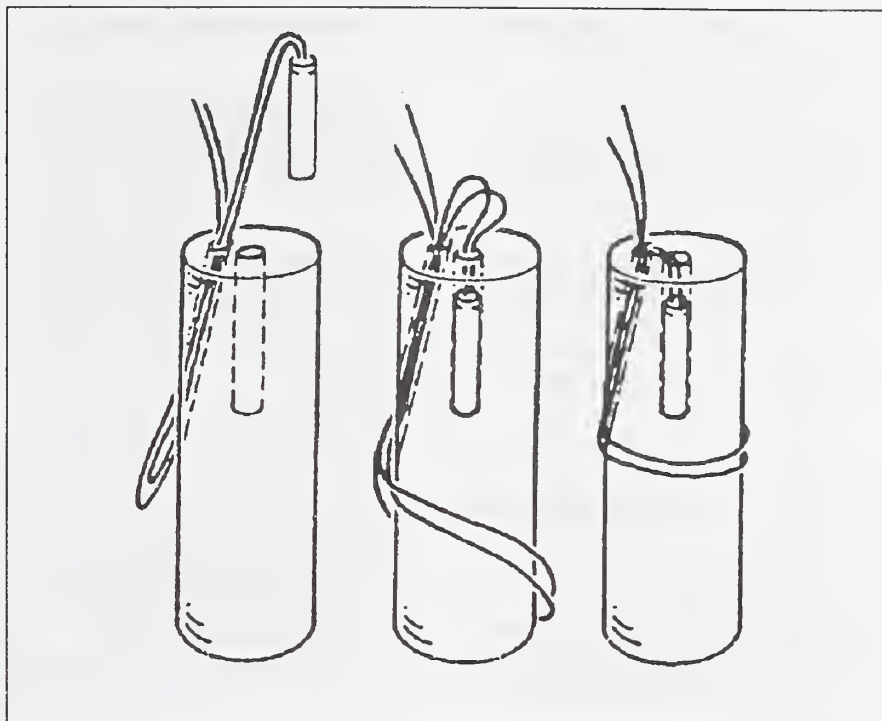


Figure 5-3.—Large diameter cartridges.

Large Diameter Cartridges (4 inches and larger in diameter) (Figure 5-3):

**Step 1:** Punch a slanting hole from the center of one end of the cartridge coming out through the side two or more inches from the end.

**Step 2:** Fold over the leg wires about 12 inches from the detonator to form a sharp bend.

**Step 3:** Push the folded wires through the hole starting at the end of the cartridge and coming out through the side.

**Step 4:** Open the folded wires and pass the loop over the other end of the cartridge.

**Step 5:** Punch another hole straight into the end of the cartridge beside the first, insert the detonator in this hole, and take up all the slack in the wires.

### 5.2.3 Exploding Bridgewire Detonators (EBW's)

Exploding bridgewire detonators (EBW's) are not subject to detonation by static electricity, stray currents, radio transmitters, etc., and may be safely used where these conditions are present.

Exploding bridgewire detonators and firing sets are manufactured by Reynolds Industries and are approved for Forest Service use. RP-80, RP 501, and RP-83 detonators may be used with detonating cord, or bulk explosives or cartridges of cap-sensitive explosives. RP-80 detonators with cord adapters are used only with detonating cord. RP80 and RP 501 detonators are directional, whereas the RP 83 detonators are not.

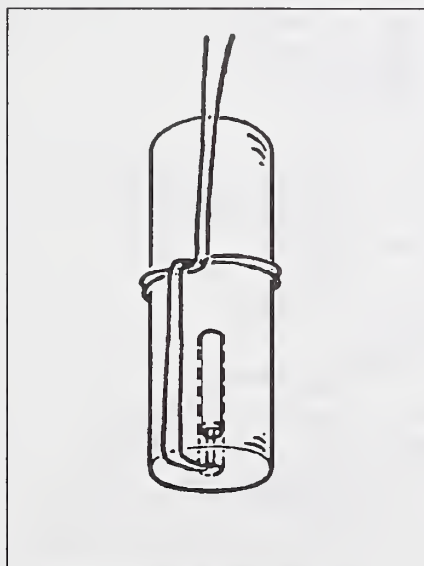


Figure 5-2.—Small diameter cartridges.

Use Reynolds FS-9 or FS-10 firing sets in accordance with the manufacturer's instruction.

Consult Reynolds Industries before firing more than two EBW's in series.

Provide enough lead wire to permit the blaster and crew to be at least 500 airline feet from the nearest explosive. Use No. 20-gauge or larger diameter copper insulated wire.

## 5.2.4 Detonating Cord

Select a detonating cord consistent with the size and physical condition of the borehole, stemming, and the type of explosive. Typically, 25 grain

downline is used in 3-inch boreholes.

Handle and use detonating cord with the same respect and care given other explosives.

Cut the line of detonating cord extending from a borehole or from a charge from the supply spool before loading the remainder of the borehole or placing additional charges.

Handle and use detonating cord with care to avoid damaging or severing the cord during and after loading and hooking up.

Make sure detonating cord connections are complete and positive in accordance with manufacturer's recommendations.

Make knot-type or other cord-to-cord connections only if the explosives core is dry (See Figure 5-4).

Keep all detonating cord trunklines and branchlines free of loops, kinks, or sharp angles that direct the cord back toward the oncoming line of detonation.

Inspect all detonating cord connections before firing the blast.

When using detonating cord millisecond-delay connectors or short-interval-delay electric blasting caps with detonating cord, strictly follow manufacturers recommendations.

When connecting a detonator to detonating cord, tape or otherwise

### Knots For Detonating Fuse Connections

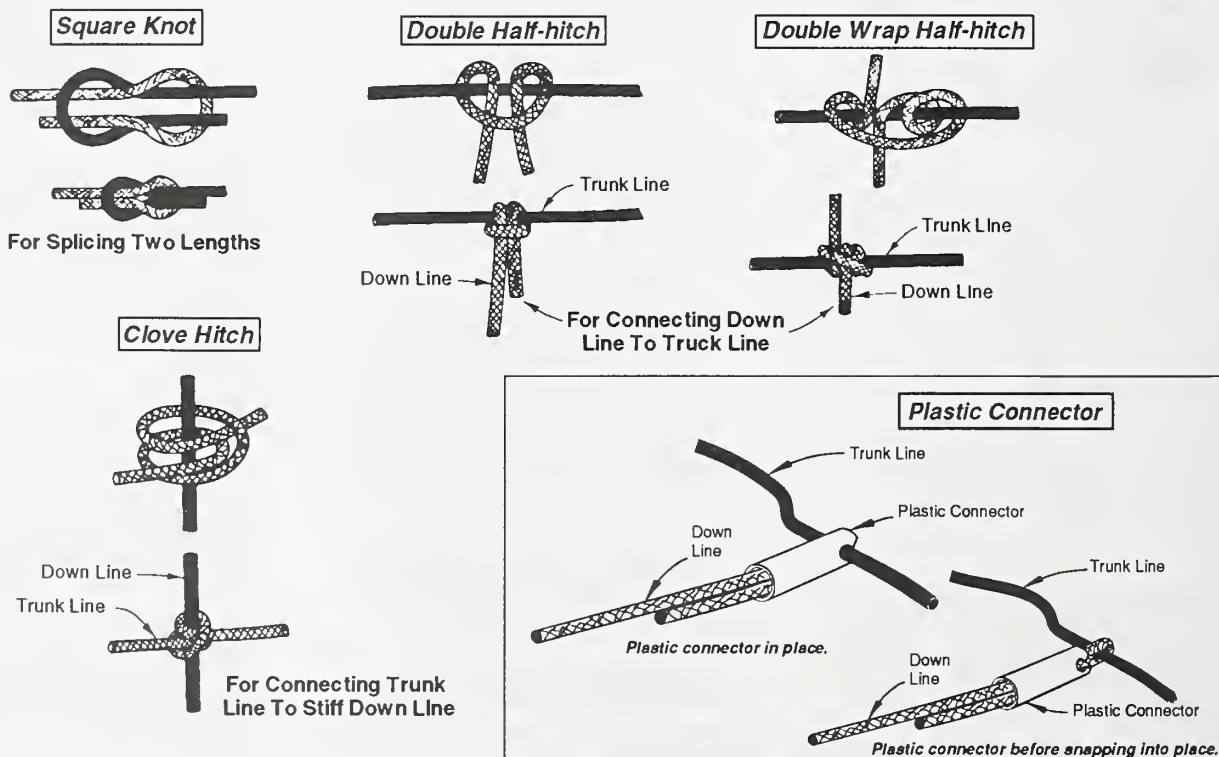


Figure 5-4.—Knots for detonating fuse connections.

attach the cap securely along the side or end of a 3-foot length of detonating cord. The end of the detonator containing the explosive charge must be pointed in the direction in which the detonation is to proceed. Tie the "pigtail" to the main line just before returning to the blasting machine.

Do not bring detonators for firing the trunkline to the loading area or attach them to the detonating cord until everything else is in readiness for the blast.

When detonating cord is used, a double line of cord with frequent cross-ties will be used throughout, so that the detonation wave can reach the explosive charges from more than one direction. (See Figure 5-5).

### 5.2.5 Drilling

Do not start drilling until all remaining butts or old holes are examined for unexploded charges. If any are found, refire them before work proceeds.

Never deepen drill holes that have contained explosives or blasting agents.

Make boreholes large enough to admit the explosives cartridges freely.

Check holes before loading to determine depth and conditions. Do not drill within 50 feet of a hole loaded with explosives.

### 5.2.6 Loading

Establish procedures that permit safe and efficient loading before loading is started. Do not load any holes, except those to be fired in the next round of blasting. After loading, immediately remove all remaining explosives and detonators from the blast area.

Tamp only with blunt wood rods or plastic tamping poles without exposed metal parts. Non-sparking metal connectors may be used for jointed poles. Avoid violent tamping. Never tamp the primer.

Tamp the last half of stemming material firmly in place. Take care not to damage detonator wires or detonating cord.

In blasting operations, no drill holes shall be sprung or chambered.

Never leave loaded holes unattended or unprotected. Blasters must schedule work to ensure loaded holes or charges will be shot before they leave the site.

Never leave explosives or blasting agents unattended at the blast site.

Only tools used for loading explosives into holes should be nearby when explosives are delivered. Keep machines and other equipment out of the area. Do not operate equipment within 50 feet of loaded holes.

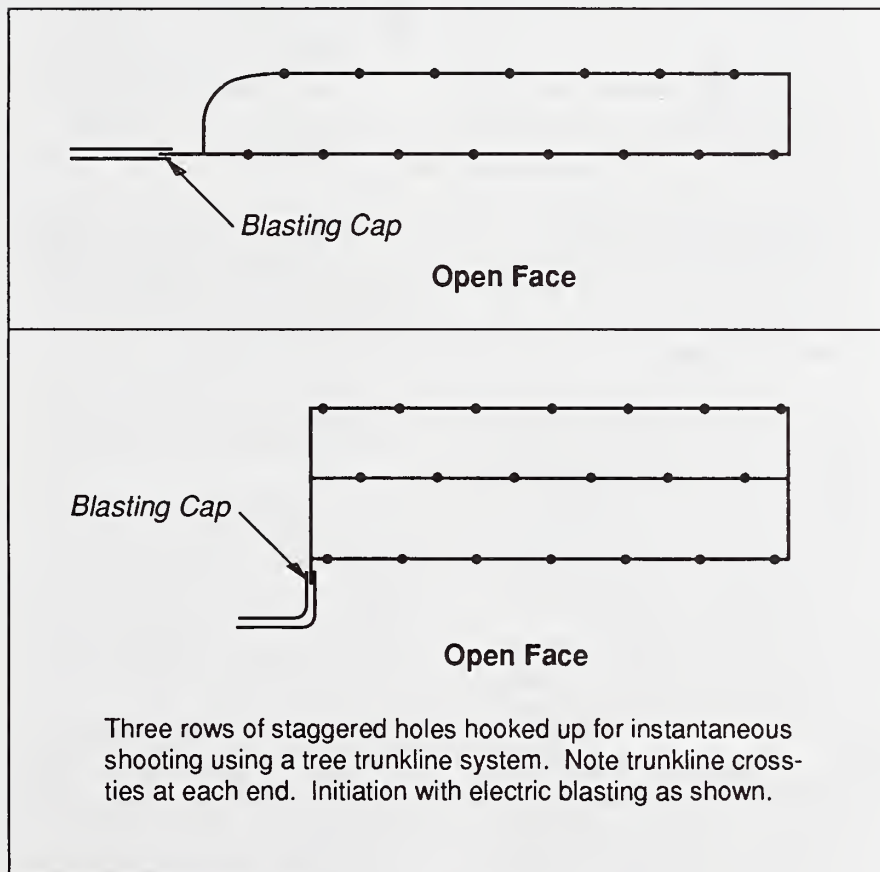


Figure 5-5.—Hookups for instantaneous firing with detonating cord.

The only activity permitted in a blast area is that required for loading holes with explosives.

If more than one blaster has been loading holes in the same area, the Blaster-In-Charge will check the wiring to ensure that all charges are properly connected in the circuit.

## 5.2.7 Wiring

Wire all caps in series. Do not wire more caps in a series than the rated capacity of the blasting machine.

For multiple shots, use standard 14-gauge or larger solid copper wire with no bare joints. Tape splices and support them off the ground. When using 20-gauge firing line, on other than EBW systems, get Regional Blaster Examiner approval.

Provide sufficient lead wire to permit the blaster and crew to be a minimum of 500 airline feet away from the nearest explosive charge.

Prevent lead wires and detonator wires from contacting any part of a telephone line, transmission line, or other electric installation.

After lead wires have been wired into the circuit with all connections tight and the wire clean, and before attaching lead wires to the blasting machine, check the circuit with an approved galvanometer or an approved blaster's ohmmeter to see if it is closed.

## 5.2.8 Firing

The Blaster-In-Charge must be assured that everyone is in a safe location. The Blaster-In-Charge is the last person to leave the blast area.

Use only approved or capacitor discharge generator blasting machines.

Capacitor discharge blasting machines are rated for a maximum number of detonators per series as follows:

- a. 32 ohms for 10-cap machines.
- b. 144 ohms for 30-cap machines.
- c. 208 ohms for 50-cap machines.

The Blaster-In-Charge of the shot shall connect the lead wires to the blasting machine.

Where practical, keep the blasting machine in a moisture-proof, locked box, and remove only when used.

Be sure safety switches are in the same position before connecting lead wires.

The Blaster-In-Charge is responsible for the blasting machine when it is not in use on the project.

### Firing Procedures:

a. Personnel must not be in front of the shot; they should be off to one side at least 500 airline feet from the nearest explosives. Vehicle and pedestrian traffic approaching the blasting area by road or trail must be stopped at least 700 airline feet from the blasting area when the first "fire" \* is given, and held until the area is cleared by the Blaster-In-Charge.

b. The Blaster-In-Charge must shout "fire"\* three times before each shot, and sufficiently in advance to permit all persons to reach a point of safety:

1. **First, the Blaster-In-Charge shouts "fire one"\*** (first call) before the circuit has been checked with the galvanometer and before connecting wires are attached to lead wires;

*\*Blasting one, two, etc" may be substituted for "fire", especially in locations where this terminology may be mistaken (i.e., Alaska).*

2. **Second, the Blaster shouts "fire two"** when the blaster reaches the blasting machine and before the lead wires are attached to the blasting machine; and

3. **Third, the Blaster-In-Charge shouts "fire three or fire in-the-hole"** after the lead wires are hooked up to the blasting machine and just before the charge is fired. Flagers answer each shout of "fire" so the Blaster-In Charge knows all is clear, the warning is heard, and that others have been warned.

c. Where noises make shouts inaudible, use bullhorns, whistles, or low-wattage radios. If radios are used when blasting with electric caps, observe the minimum distances shown in Tables 5-1 through 5-5. These limits on radio use do not apply when using EBW's or Nonel.

d. All personnel must face the blast, with backs to the sun if possible, to provide the best chance to watch for and avoid flying debris. They must also be in the safest direction from the blast to avoid fumes.

e. Immediately after the blast, the Blaster-In-Charge disconnects the lead wires from the machine, twists the bare ends together, and secures the machine so it cannot be activated.

**Table 5-1.—Recommended Distances for Commercial AM Broadcast Transmitters 0.535 to 1.605 MHz.**

<b>Transmitter Power<sup>(1)</sup> (Watts)</b>	<b>Minimum Distance (Feet)</b>
Up to 4,000	750
5,000	850
10,000	1,200
25,000	2,000
50,000 <sup>(2)</sup>	2,800
100,000	3,900
500,000	8,800

(1) Power delivered to antenna.  
(2) 50,000 watts is the present maximum power of U.S. broadcast transmitters in this frequency range.

**Table 5-2.—Recommended Distances for Transmitters up to 30 MHz (Excluding AM Broadcast) Calculated for a Specific Loop Pickup Configuration<sup>(1)(2)</sup>**

<b>Transmitter Power<sup>(1)</sup> (Watts)</b>	<b>Minimum Distance (Feet)</b>
100	750
500	1,700
1,000	2,400
5,000	5,500
50,000	17,000
500,000 <sup>(4)</sup>	55,000

(1) Based on the configuration shown in Fig. 2b using 20.8 MHz which is the most sensitive frequency.  
(2) This table should be applied to International Broadcast Transmitters in the 10-25 MHz range.  
(3) Power delivered to antenna.  
(4) Present maximum for International Broadcast.

**Table 5-3.—Recommended Distances of Mobile Transmitters Including Amateur and Citizens' Band Minimum Distance (Feet).**

<b>Transmitter<sup>(1)</sup> Power (Watts)</b>	<b>MF 1.6 to 3.4 MHz Industrial</b>	<b>HF 28 to 29.7 MHz Amateur</b>	<b>VHF 35 to 36 MHz Public Use 42 to 44 MHz Public Use 50 to 54 MHz Amateur</b>	<b>VHF 144 to 148 MHz Amateur 150.8 to 161.6 MHz Public Use</b>	<b>UHF 450 to 470 MHz Public Use</b>
10	40	100	40	15	10
50	90	220	90	3s	20
100	125	310	130	50	30
180 <sup>(2)</sup>	-	-	-	65	40
250	200	490	205	75	45
500 <sup>(3)</sup>	-	-	290	-	-
600 <sup>(4)</sup>	300	760	315	115	70
1,000 <sup>(5)</sup>	400	980	410	150	90
10,000 <sup>(6)</sup>	1 250	-	1,300	-	-

Citizens Band (Walk e-Talkie) 5 watts Minimum Distance 5 ft–26 96 to 27 23 MHz

(1) Power delivered to antenna.  
(2) Maximum power for two-way mobile units in VHF (150.8 to 161.6 MHz range) and for two-way mobile and fixed station units in UHF (450 to 460 MHz range).  
(3) Maximum power for major VHF two-way mobile and fixed station units in 35 to 44 MHz range.  
(4) Maximum power for two-way fixed station units in VHF (150.8 to 161.6 MHz range).  
(5) Maximum power for amateur radio mobile units.  
(6) Maximum power for some base stations in 42 to 44 MHz band and 1.6 to 1.8 MHz band.

**Table 5-4.—Recommended Distances For VHF TV and FM Broadcasting Transmitters.**

<b>Effective Radiated Power (Watts)</b>	<b>Minimum Distance (Feet)</b>	
	<b>Channels 2 to 6 and FM</b>	<b>Channels 7 to 13</b>
Up to 1,000	1,000	750
10,000	1,800	1,300
100,000 <sup>(1)</sup>	3,200	2,300
316,000 <sup>(2)</sup>	4,300	3,000
1,000,000	5,800	4,000
10,000,000	10,2000	7,400

(1) Present maximum power channels 2 to 6 and FM 100,000 watts.  
(2) Present maximum power channels 7 to 13–316,000 watts.

**Table 5-5.—Recommended Distances From UHF TV Transmitters.**

<b>Effective Radiated Power (Watts)</b>	<b>Minimum Distance (Feet)</b>
Up to 10,000	600
1,000,000	2,000
5,000,000 <sup>(1)</sup>	3,000
100,000,000	6,000

(1) Present maximum power channels 14 to 83 – 5,000 000 watts.

*From Institute of Makers of Explosives, Publication 20, Safety Guide for the Prevention of Radio Frequency Radiation Hazards in the Use of Electric Blasting Caps (March 1971)*

## 5.2.9 Static Electricity

Take precautions to prevent accidental firing of electric blasting caps from current induced by radar, radio transmitters, lightning, adjacent powerlines, dust storms, clothing, portable electric cables for equipment, or other sources of extraneous electricity.

a. Do not throw electric blasting cap leg wires through the air. Unfold or unroll near the ground.

b. Shunt EBC detonators in holes that have been primed and loaded until wired into the blasting circuit.

c. Do not load boreholes when an electrical storm is in progress or approaching.

*(1) If holes are loaded and a storm occurs, keep the danger area clear and post flaggers in the same manner as when shots are fired.*

*(2) If holes are loaded, but not connected to the lead wire, do not shunt the series; leave it open.*

d. Use detonating cord or other non-electric system in place of electric blasting caps in powerline areas. If the current cannot be interrupted, use EBW's or non-electric detonators on work within 300 feet of the line. EBW's and non-electric detonators must also be used within the minimum distance (as described in IME Publication No. 20) from a permanent radio or tv transmitting station (See tables 5.1 through 5.5, page 65).

e. *Clothing.* Although not a major cause of accidental detonation, clothing can generate enough static electricity to

detonate electric blasting caps. The most hazardous condition occurs when wearing clothing of different fabrics, particularly wool when worn with dacron or nylon on a dry, cold day. Take these precautions:

*(1) Wear cotton or wool. Avoid wearing synthetics such as dacron or nylon, particularly with wool garments.*

*(2) Do not remove coat or sweater while working with detonator.*

*(3) Discharge static electricity by grounding body for at least 10 seconds.*

*(4) When hazardous amounts of static electricity exist, use EBW's or non-electric initiation systems.*

## 5.2.10 Post Blast Procedures

After firing the shot, the Blaster-In-Charge:

a. Allows sufficient time for smoke and fumes to dissipate before returning to blasting area;

b. Gives a positive "all clear" signal before personnel return to the blast area or traffic flow is resumed; and

c. Traces wires through the broken rock and conducts a search for any unexploded cartridges and misfires before work is resumed or the crew is allowed to return to the area.

safeguards to exclude employees from the danger zone.

All work shall cease except that necessary to remove the hazard of the misfire. Only those employees needed to do the work shall remain in the danger zone.

With electric blasting caps or non-electric detonation systems, wait at least 30 minutes. If the misfire is considered electrical, before going back to the danger area to recheck the wiring, disconnect the lead wires, and check again with the galvanometer for a load exceeding the firing capacity of the blasting machine and for a broken or grounded circuit.

***If there is any reason to believe a charge is burning in a hole, the blaster must evacuate the danger area and post and guard it for 12 hours.***

If possible, another detonator shall be inserted into the shot and fired again.

If a misfire is in solid material and has been stemmed with water, another primer shall be prepared, placed on top of the first charge, and fired again.

If a misfire is in solid material and has been stemmed or tamped with dirt, or clay, the packing or stemming material shall be blown out with compressed air from a semi-conductive hose or washed out with water. When enough of the stemming material has been removed to expose explosives in the hole, another primer shall be prepared, placed, and the blast refired.

***Note: No drilling, digging, or picking shall be permitted.***

***After the blast, make a careful search for undetonated explosives.***

***Explosives recovered from blasting misfires shall be disposed of as directed in Section 5.4 or placed in a separate magazine until com-***

## 5.3 Misfires

If a misfire is found, the Blaster-In-Charge must provide proper

**petent personnel have determined the method of disposal. Caps recovered from blasting misfires shall not be reused and shall be disposed of as described in Section 5.4. (See page 67)**

Most misfires are due to some problem with the initiation system such as failure to make a connection, a broken lead wire, or simply not understanding the initiation system. Other causes of misfires are inadequate priming, and malfunctioning explosives due to improper storage.

Detection of a misfire is no problem if none of the holes detonate. However, if a few holes or portions of a single hole fail to detonate, detection of the misfire can be very difficult and dangerous. In these cases visual inspection of the muck pile for undetonated explosives and boulders or other irregularities that suggest possible misfires is the most reliable detection method.

Disposal of detected misfires is accomplished by removing the explosives with water or air flushing, repriming and reshooting, or by detonating a nearby charge. Be aware, however, that detonating a nearby charge can be very dangerous and is not recommended.

The best way to avoid misfire accidents and costs is to eliminate their causes. This can be done by knowing the characteristics of the explosives, delays, and initiation system, proper blasting design, taking care in loading the shot and hooking up the initiation system, and by maintaining good housekeeping practices at the blasting site.

## 5.4 Disposing of Deteriorated or Damaged Explosives

### 5.4.1 General

Explosives that have deviated from normal color, condition, texture, size, or that have been damaged shall be considered deteriorated or unusable until their exact condition is determined by expert opinion.

Only personnel certified for disposal will be involved in the movement and disposal of deteriorated or damaged explosives. Exercise extreme caution when attempting to move deteriorated explosives, especially if there is any sign of leakage or crystallization. When in doubt seek help from the explosive manufacturer or your State Police bomb squad. Err on the side of caution.

Destroy only one type of explosive at a time.

To destroy explosives by detonating, pick a site where access can be controlled and noise, flyrock, and possible fire will do no damage to persons or property.

**a.** Destroy small amounts (maximum of 50 pounds) at a time.

**b.** If possible place explosives in a hole with a primer of new explosives. Proceed with the shot as described in Section 5.2.8.

**c.** Maintain proper distance from explosives.

If burning is necessary, keep in mind that burning some explosives can cause them to detonate and

they should be treated as if they will. Proceed with burning as follows:

**a.** Do not burn explosives in deep piles. Spread sticks about an inch apart.

**b.** Empty boxes, paper, and fiber packing materials that have previously contained high explosives shall not be used again for any purpose. Make sure they are empty, then destroy by burning at an approved location.

**c.** Keep disposal area clear of personnel until all debris is cooled.

**d.** Do not place explosive on hot ground.

**e.** Do not stir or add explosives after burning is started.

**f.** Exercise care to prevent disposal crews from inhaling fumes from burning explosives.

**g.** Maintain proper quantity-distance from explosives.

### 5.4.2 Dynamite

Do not attempt to move any deteriorated nitroglycerin based product that cannot be destroyed in place by detonating. Leave a guard in the area and call your State Police bomb squad.

### 5.4.3 Other Explosives

Some explosives, particularly the newer ones, may require disposal techniques other than detonating or burning. For example a two component explosive (fertilizer) usually can be deactivated by diluting the mixed explosive with an ample supply of water and

spreading it on mineral soil adjacent to a road or trail or a borrow pit area.

Consult the explosives manufacturer for specific disposal practices and recommendations. Explosives manufacturers have agreed to take explosives that are damaged, unusable, or deteriorated.

## 5.4.4 Detonators

Destroy all delay or instant electric blasting caps that have so deteriorated from age or improper storage that they are unfit for use. Such caps may be very dangerous to handle. They should not be disturbed until an experienced blaster certified for disposal or a technical representative of the manufacturer has an opportunity to check them.

Detonators that have deteriorated or have been proved defective by a blaster's ohmmeter should be destroyed with an explosive or returned to the manufacturer. Corrosion is one sign of deterioration.

Do not throw detonators into wells or any body of water such as water-filled abandoned quarries.

If required, destroy detonators as follows:

a. Separate the detonator from the shunted wire by about a foot. Do not remove the shunt. Keep the rest of the wire coiled as originally packed. Prepare no more than 50 detonators and place in a hole where they will be confined.

b. Make up an explosive charge that will cover the detonators and prime the charge with a good detonator or detonating cord.

c. After shooting thoroughly, examine the ground around the shot to be sure no unexploded detonators remain.

d. Do not use the same area for successive shots unless the entire area feels cool.

## 5.4.5 Detonating Cord

Detonating cord can be disposed of in the same manner as detonators by confining it in a hole, putting a charge on top and detonating.

## 5.4.6 Ammunition

See 6.1 Avalanche Blasting, page 81.

# 5.5 Blast Design

## 5.5.1 Rules of Thumb for Blast Design

Nearly every occupation or discipline has its own particular "rules of thumb," and blasting is no exception. These are rules, not law. They are a set of guidelines based on practical experience and technical information. Blasting projects vary so much that there can be no set of rules to cover every possible contingency. Be sure that the advantage gained from breaking the rule is greater than the penalty to be paid for that violation.

**Rule 1 – The detonation velocity of the explosive should match, as closely as possible, the sonic velocity of the rock to be blasted.**

The need for matching detonation (VOD) and sonic (VSO) velocities

becomes apparent when the mechanics of rock breakage are considered. The speed at which an acoustical wave travels through rock is determined by the **structure of the rock**, not by the VOD of the explosive. The compressive and tensile waves generated by the detonation process will travel through the rock at a fixed speed, regardless of the rate at which they are generated. There is reflection and cracking at any open plane of separation, such as a free face or borehole. The waves are omnidirectional, and therefore travel up the borehole, as well as all other directions, reflect and begin cracking along the long axis of the borehole. If the detonation process is slower than the speed at which the rock mass will transmit shock waves, there will be cracking along the borehole ahead of the detonation of the explosive in the borehole.

If detonation proceeds at the same, or close to the same, speed as the transmission of shock waves, the resulting breakage will be optimum, more uniform, and equal along the entire explosive column. Maximum borehole spacings and burdens can then be used.

There is no value in using an explosive that has a VOD greatly in excess of the VSO of the rock. Any speed gained at the point of initiation is lost by immediate attenuation of the wave to the speed of transmission determined by the VSO.

When selecting an explosive to match up the VSO of a rock mass, there is no need to match the VOD of the explosive to within a few feet per second of the VSO of the rock. Variance in the velocities below 10 percent either way should be more than sufficient.

**Rule 2 – Always select the most dense explosive possible, consistent with water, loading conditions, and final cost.**

The more dense the explosive, the more of it you can put in a borehole of a given size. The sensitivity of an explosive is determined by the relationship of the weight of 1 cubic centimeter of the explosive to the weight of 1 cubic centimeter of distilled water. If the two weights are equal, the explosive has a density of 1.0 g/cc, and if the weight of the explosive is 1.4 times that of the water, the explosive is said to have density of 1.4.

For example: A single borehole 3.5 inches in diameter and 33 feet deep will hold, if stemmed 8 feet, 127.5 pounds of an explosive with a density of 1.25 g/cc. An approximation used for this calculation is:

$$\frac{De \times C^2 \times L}{3} = \frac{1.25 \times (3.5)^2 \times L}{3} =$$

$$5.1 \times 25' \text{ to load } (33' - 8' \text{ stem}) =$$

$$127.5 \text{ lbs/hole}$$

Where:

De = Density.

C = Borehole diameter in inches.

L = Borehole depth less stemming in feet.

If an explosive with the same VOD but with a density of 1.4 g/cc were used in that borehole, the amount of explosive which can be loaded in the hole increases to 142.5 lbs.

$$\frac{De \times C^2 \times L}{3} = \frac{1.40 \times (3.5)^2 \times L}{3} =$$

$$5.7 \times 25' = 142.5 \text{ lbs/hole}$$

If a powder factor of 1 pound per cubic yard is required, the spacing and burden for the explosive with

the density of 1.4 will be greater than that for the explosive with a density of 1.25.

**Rule 3 – Select explosives according to the characteristics of the rock formation to be blasted.**

Although Rule 1 states that explosives should be selected on the basis of matching VOD to VSO, there are many instances where the structural characteristics of the rock formation allow use of less expensive lower velocity explosives (i.e., ANFO).

In those instances where the planes of separation in the rock are smaller than the degree of fragmentation required, the rock can often be blasted by merely "bumping" the rock with explosives. A close study of the breakage planes in the rock mass will dictate whether or not a lower velocity explosive may be used. This subjective determination hinges upon knowledge of the rock and experience with varying rock formations. If there is any doubt that a particular formation will allow bumping, it is best to plan the blasting for the "worst case" formation.

**Rule 4 – When using slurry or water gel explosives, always determine the critical temperature below which the explosive will fail to reliably detonate.**

Almost all slurry explosives have a critical temperature below which they may not detonate, or may not sustain detonation in elongated columns. This critical temperature is usually noted in the technical data sheets supplied to the consumer by the manufacturer or distributor. Under no circumstances should the explosive be used when the

temperature of the explosive at time of loading is below that critical temperature.

In addition to the temperature of the explosive itself, consider the temperature of water that may be in the borehole, since slurry products are often used in wet boreholes. In many parts of the U.S., particularly in the northern states during winter months, it is not unusual for water temperature in the boreholes to be below the critical temperature of the explosive.

**Rule 5 – When using the relationship between characteristic impedance and detonation pressure to determine a characteristic powder factor, always remember that blasts to a free face should have a design powder factor of between .75 and 1 pound per cubic yard:**

If the calculated design powder factor is over 1 pound per cubic yard when shooting to a free face, the explosive used in the calculations has either too low a density or too low a VOD for the rock being blasted.

If the calculated powder factor is less than .75 pounds per cubic yard when shooting to a free face, the explosives used in the calculations have either too high a density or too high a VOD for the rock being blasted.

In blasts where there is no free face and one must be created by the use of delays, the design powder factor should be between 1.25 and 1.5 pounds per cubic yard. Initially, the free face created by the detonation of the lower periods of delay will be the surface. It is advisable to make the opening shot relatively

shallow, because it is harder to get breakage all the way to the bottom of the shot under these circumstances.

### 5.5.2 Rules of Thumb for Blasting Geometry

**Rule 1 – The distance between holes (spacing) should not be greater than one-half the depth of the borehole.**

When the effect of a blast is simulated on graph paper using an assumed or idealized angle of breakage of 90 degrees, the diagrams indicate that in each instance where the distance between holes in a row is greater than one-half the depth of the hole, the angles of breakage intersect so far above the bottom of the holes that the primary relief for each hole is to the surface. This causes both a great deal of vertical throw and a very uneven bottom. The greater the disparity between depth and spacing, the more pronounced the effect will be, to the point where the angles of breakage intersect above the surface of the shot.

**Rule 2 – In any blast where there is hole for hole delay, the spacing to burden relationship should be 6 to 5.**

Several investigators into the science of rock mechanics have suggested that the optimum spacing to burden relationship should be 2:1, with the burden being equal to one-half the spacing (Figure 5-6). Field experience shows that this relationship has two drawbacks. First, the blaster may assume that this relationship will apply when there is no delay system at work, when in fact, the optimum spacing to burden relationship in all instantaneous blasts should be 1:1

to insure equal distribution of explosives in the blast. Second, if an instantaneous blast is fired with a spacing to burden relationship of 2:1, the back wall of the blasted area will, in most cases, be "saw-toothed."

When delays are used, particularly when there is hole for hole and row for row delay with no two holes firing on the same period, the angle of breakage approaches the idealized ratio of 2:1. The slight addition of burden avoids the possibility of "blow out," or violent throw from relieved burdens during

the shifting of burden from one hole to another.

**Rule 3 – Stemming should be equal to the burden.**

The purpose of stemming, it has long been assumed, is to return the borehole to its original condition as much as possible in order to reduce noise, and possibly rifling at the top portion of the hole. Stemming serves other purposes as well.

If the explosive detonation process takes place up the borehole, the

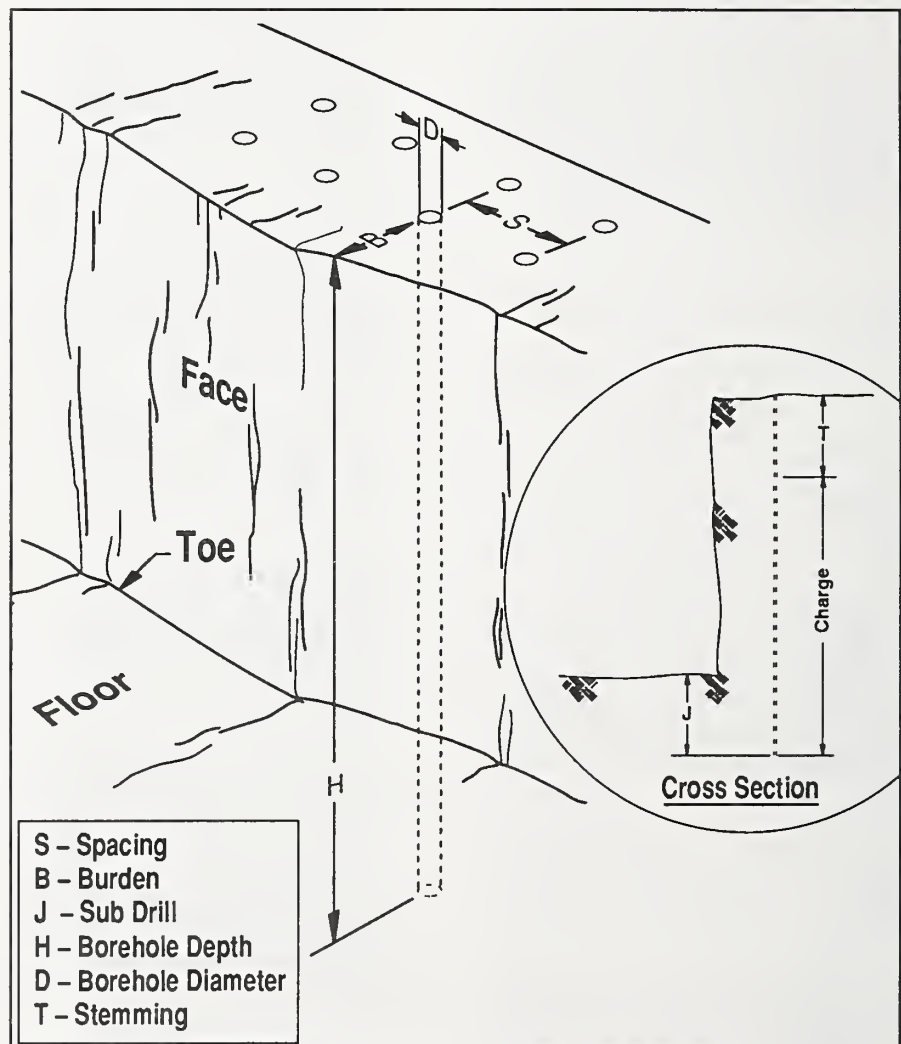


Figure 5-6.—Typical rock blasting layout.

surface of the rock above the stemming is as much a free face (assuming there is a free face) as the free face that is parallel to the boreholes. If the stemming is less than the distance of the burden, the rock in the area of the stemmed portion of the hole has already been broken by the time detonation of the explosives in the top portion of the hole has taken place. If the stemming is greater than the burden, the rock at the top of the borehole will have less cracking from reflection and refraction of compressive and tensile waves. Obviously, then, stemming should equal burden, and be of such material as to return the rock close to its original condition. Drill fines, tamped into the hole, are ideal.

**Rule 4 – Sub-drill should be between .3 and .5 of spacing.**

Some investigators state that sub-drill should be equal to .3 of burden. This is true in instances where spacing and burden are equal, such as with instantaneous blasts. It will also work when there is row for row delay. In blasts where the delay system is both row for row and hole for hole, however, the sub-drill should be determined by the largest dimension, which is the spacing. An average sub-drill of .4 of spacing is best to use for planning purposes.

### 5.5.3 The Unified Rock Classification System and Determination of VSO

A systematic approach to blasting requires essential information about the rock to be blasted. A heavy rock will require a given

amount of explosive to move it; a light rock will require less. There is a difference between rocks that have large crystals and those which are fine grained. There are rocks that will break along predetermined planes and those that break randomly. All of these conditions require specific geological knowledge. Douglas-Williamson, Engineering Geologist for the USDA Forest Service, Region Six, developed the United Rock Classification System (URCS) to define the major strength and behavior parameters of rock without going into the fine details of type classification. The URCS is engineering shorthand that can be reliably used to show the blasting characteristics of rock.

With the use of the URCS and the 1 pound ball peen hammer, a

quick and surprisingly accurate estimate of the VSO of a rock mass can be made. The URCS is used by geologists and road designers to determine the unconfined compressive strength of materials. Blasting requires the VSO instead. An adjustment has been made, changing information gathered by the hammer test from unconfined compressive strength in psi to VSO in feet per second.

Select a fresh piece of rock (free of weathering) and hit it with the rounded part of a 1 pound ball peen hammer. There are four distinct reactions to the impact. The reaction is independent of intensity of the blow within the limitations of the tool used and the investigator's strength. The reactions are termed "Craters," "Dents," "Pits," and "Rebounds" (See Figure 5-7).

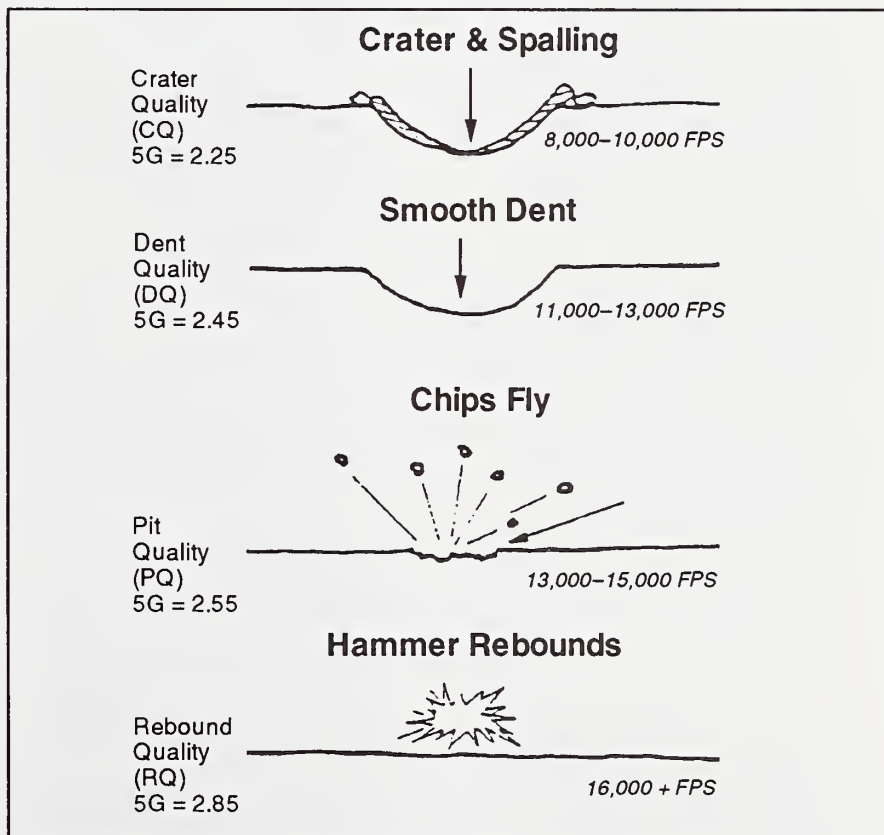


Figure 5-7.—Sonic velocity as indicated by the strike of a one-pound ball-peen hammer.

Crater quality rock material is a reaction under point of impact producing a shearing and up-thrusting of adjacent mineral grains. This category has an estimated VSO (Sonic Velocity) of from 8,000 to 10,000 fps. The rock material can usually be recovered during rock core drilling operations, has high absorption, and will respond to freeze/thaw stresses by at least cracking and checking. It has a very low energy transfer when impacted by explosives. It can often be ripped and excavated without blasting.

Dent quality rock material has a reaction that produces a "dent" or depression under the point of impact. It indicates the presence of "pore space" between the mineral grains. This category or quality of material has an estimated VSO of from 11,000 to 13,000 fps and is roughly equivalent to the strength range of concrete, but does not respond to blasting in the same manner as does concrete. Dent Quality material has low energy transfer in response to blasting and often produces "boulders and sand."

Pit quality rock material has a reaction that produces "explosive" departure of mineral grains under the point of impact, which results in a shallow, rough pit. This quality of specimen has a VSO of between 13,000 and 15,000 fps and is considered "hard" rock by the construction industry.

Rebound quality rock material has no "reaction" to impact and is a true "brittle-elastic" substance, in a mechanical sense. This category of material has an estimated VSO in excess of 15,000 fps. Breakage is often sharp and angular due to the brittleness of the material. It also has a very high energy transfer in response to blasting; burdens and spacings can be extended.

Using the **Mineral Grain Bonding Element** classification, the correlations between unconfined compressive strength and VSO are as follows:

Moldable - MBL:	No blasting required
Crater - CQ:	VSO - 8,000 - 10,000 fps
Dent - DQ:	VSO - 11,000 - 13,000 fps
Pit - PQ:	VSO - 13,000 - 15,000 fps
Rebound - RQ:	VSO - 16,000 + fps

Overlap between elements is immediately apparent. There is also an overlap in the actual responses to the hammer test. With some practice the blaster can make these determinations, even when the response is not conclusive. The estimate will be somewhat subjective, but it requires only a little practice and care to make a remarkably accurate determination of VSO.

#### Determination of Specific Gravity:

*The specific gravity of rock can also be estimated by using the URCS/Method as follows:*

MBL - 1.7 - 2.1
CQ - 2.2 - 2.3
DQ - 2.4 - 2.5
PQ - 2.5 - 2.6
RQ - 2.7 - 3.0+

### 5.5.4 Characteristic Impedance Z

Characteristic impedance, symbolized by the letter Z: (Scientific notation for electrical impedance), is the product of the mass of the rock, and its VSO. It is used in blasting primarily to evaluate the rock's resistance to movement, and its "blastability."

The modified formula to determine the characteristic impedance of rock is:

$$Z = 1.31 \times SG \times \frac{VSO}{1,000}$$

Where:

SG = Specific gravity of the rock.  
VSO = Sonic velocity of the rock.

### 5.5.5 Kilobars of Detonation Pressure K

The formula to determine kilobars of detonation pressure K is:

$$K = \frac{.418 \times De \times \left(\frac{VOD}{1,000}\right)^2}{.8 De + 1}$$

Where:

De = Density of the explosive  
VOD = Detonation velocity of the explosive

### 5.5.6 Characteristic Powder Factor (CPF)

For blasting purposes the Z of rock and K of the explosive is necessary to assist in making a determination of the "Characteristic Powder factor" (CPF). The Characteristic Powder Factor (CPF) is that powder factor which is based upon the known characteristics of the rock and the known characteristics of the explosives.

Matching the Z of the rock with the K (kilobars of detonation pressure) of the explosive aids in determining one or all of the following:

a. That the explosive is matched to the rock.

b. That the Powder Factor indicated falls within the proper range for the type of blasting required.

c. That the blasting calculations are based on known quantities and qualities of both rock and explosives.

The formula to determine CPF is:

$$CPF = \frac{Z}{K}$$

### 5.5.7 Examples for Estimating Blasting Projects

These formulas are used throughout this step-by-step method of planning and estimating blasting projects. They are, for the most part, simplified versions of long and tedious mathematical calculating which can be confusing. The formulas, and the estimating system to which they are fitted, have been tried and tested both in practice and in the classrooms of a great number of seminars and training sessions.

a. To determine the Z of rock (Characteristic Impedance)

$$Z = 1.31 \times SG \times \frac{VSO}{1,000}$$

Where:

SG = Specific gravity of the rock  
VSO = Sonic Velocity of the rock

Example:

If SG is 2.5, and VSO is 15,000 fps:

$$Z = 1.31 \times 2.5 \times 15 = 49.12$$

b. To determine K of explosive (Kilobars of Detonation Pressure)

$$K = \frac{.418 \times De \times \left(\frac{VOD}{1,000}\right)^2}{.8 De + 1}$$

Where:

De = Density of the explosive  
VOD = Detonation velocity of the explosive

Example:

If De = 1.25, & VOD = 15,500 fps

Then,

$$K = \frac{.418 \times 1.25 \times 240.25}{(.8 \times 1.25 + 1)} =$$

$$\frac{125.53}{2} = 62.76$$

c. To determine CPF (Characteristic Powder Factor)

$$CPF = \frac{Z}{K}$$

Where:

Z = Characteristic impedance of rock  
K = Detonation pressure of explosive.

Example:

If Z = 49.12 and K = 62.76

Then,

$$CPF = \frac{Z}{K} = \frac{49.23}{62.76} = .78 \text{ CPF}$$

If the CPF is between .75 pounds/cy and 1 pound/cy, the right explosive has been selected. If the CPF is higher than 1 pound/cy, the explosive has a VOD or density which is too low for the rock. If the CPF is below .75 pound/cy, the explosive has a VOD or density which is unnecessarily high (see Rule of Thumb No. 5).

d. To determine cubic yards of rock per foot of borehole with known burden and spacing:

$$\frac{S \times B}{27} = \text{Yards}^3/\text{foot}$$

Where:

S = spacing  
B = burden

Example:

If spacing is 12 feet and burden is 10 feet.

Then,

$$\frac{12 \times 10}{27} = 4.444 \text{ yards}^3/\text{foot}$$

e. To determine cubic yards of rock for an entire borehole of known depth

$$\frac{S \times B \times HDg}{27}$$

Where:

S = spacing  
B = burden  
HDg = depth of hole To Grade

Example:

If S = 12', B = 10', and HDg = 30'

$$\frac{12 \times 10 \times 30}{27} = \frac{3,600}{27} = 133.33 \text{ cyds}$$

f. To determine pounds of explosives per foot of borehole when the density of the explosive and the charge diameter are known

$$\text{Pounds/ft} = De \times \frac{C^2}{3}$$

Where:

De = Density of explosive  
C = Charge Diameter\*

\*In the case of pourable explosives which fill the entire hole, the charge diameter is the diameter of the borehole.

Example:

If  $De = 1.3$  and  $C = 3.5"$

$$De \times \frac{C^2}{3} = \frac{1.3 \times 12.25}{3} =$$

5.31 pounds/ft

g. To determine pounds of explosives per borehole when the density of the explosive, the charge diameter, and the depth of the borehole are known.

$$\frac{De \times C^2 \times (HD - Ts)}{3}$$

Where:

De = Density of explosive

C = Charge diameter\*

HD = Total depth of hole

Ts = Feet of stemming

\*In the case of pourable explosives which fill the entire hole, the charge diameter is the diameter of the borehole.

Example:

If  $De = .85$ ,  $C = 3$  inches,  $HD = 35$  feet and  $Ts = 10$  feet,

$$P = \frac{.85 \times 9 \times 25}{3} = 63.75 \text{ pounds}$$

h. To determine the number of holes required to produce a given amount of rock:

$$\frac{\text{Cubic Yards Required}}{\text{Cubic Yards of Rock/Hole}}$$

Example:

If 25,000 cubic yards of rock are required from a pattern producing 133.33 cubic yards per borehole,

$$\frac{25,000}{133.33} = 188 \text{ Holes (187.5)}$$

i. To determine spacing

$$S = 3\sqrt{\frac{De \times C^2}{CPF}}$$

Where:

De = Density of explosive

C = Charge diameter

CPF = Characteristic powder factor

Example:

If  $De = 1.25$ ,  $C = 3.5$  inches, and  $CPF = .79$  pounds/cy

$$3\sqrt{\frac{1.25 \times 12.25}{.79}} = 3\sqrt{\frac{15.31}{.79}} =$$

$$3\sqrt{19.38} = 3 \times 4.4 = 13.2 \text{ feet}$$

Spacing is customarily rounded off to the nearest foot.

j. To determine burden:

Burden is to spacing as 5 is to 6;

$$B = \frac{S \times 5}{6} \text{ or } B = S \times .833$$

Where:

S = Spacing

Example:

If  $S = 13$  feet,

$$B = 13 \times .833 = 10.8 \text{ feet}$$

Like spacing, burden is customarily rounded off to the nearest foot.

k. To determine sub-drill,

SD = .3 to .5 of Spacing

(An average of .4 serves for planning purposes)

Example:

If  $S = 13$ ,

$$SD = 13 \times .4 = 5.2 \text{ feet}$$

Like spacing and burden, sub-drill is rounded off to the nearest foot or half foot, depending upon the characteristics of the rock.

l. To Determine Stemming,

$$Ts = B$$

Where:

B = Burden

Example:

If  $B = 10$  feet, then  $Ts = 10$  feet.

m. To determine total footage of drilling required,

Total drill footage = Number of holes  $\times$  HD

Where:

HD = Total depth of hole including sub-drill

Example:

If 188 holes are required to produce a given amount of rock, and the total depth of each hole is 35 feet,

$$188 \times 35 = 6,580 \text{ feet.}$$

## 5.6 Ground Vibration and Airblast

a. Ground vibrations and airblast damage may become a serious problem to any blasting operation that must be carried out around populated areas, facilities, or structures. The Bureau of Mines has conducted many studies on the subject of ground vibrations and airblast as it relates to surface mining.

These studies have determined that particle velocity is the best criterion for predicting the probability of structural damage due to ground-borne vibrations. If the limits of most loading are followed to eliminate damaging ground vibrations, then the airblast hazard is usually compensated for automatically.

b. To maintain vibration within acceptable limits the Bureau of Mines studies have determined that a peak particle velocity of 2 inches per second adjacent to a structure will result in the probability of little vibration damage. The further limiting of peak velocity to 0.4 inches per second should minimize complaints from adjacent property owners. The Surface Mining Control and Reclamation Act (P.L. 95.87) limits the maximum particle velocity to 1 inch per second, and this is the standard that shall be followed in Forest Service blasting. In the absence of instrumentation, use a scaled distance of 60 times the square root of the weight of the charge as the minimum safe blasting distance.

c. Usually the distance from the blast area to the nearest structure is fixed. To determine the amount of explosives per delay period of 8 milliseconds or greater that is permissible, use the following procedure:

$$D/\sqrt{W} > 60$$

That is, the distance in feet (D) from the blast to the point of concern divided by the square root of the charge in pounds per delay (W), should equal 60 or more.

d. As an example of use:

1. 25 lb/delay of explosives are to be used in a shot. A house is 350 feet from the blast site.

$$\frac{350}{\sqrt{25}} > 60 \quad \text{or}$$

$$\frac{350}{5} = 70 > 60$$

Because 70 is greater than 60, the loading in relation to the house is within the safe limit.

e. The nearest house is 2,000 feet away. How much explosive per delay can be used and still be safe?

$$D\sqrt{W} = 60 \quad \text{or}$$

$$\sqrt{W} = D/60$$

$$\sqrt{W} = 2,000/60$$

$$\sqrt{W} = 33.33$$

Then  $W^2 = 1,110$  lbs

1,110 pounds per delay can be used and still be safe.

f. 36 pounds per delay is used in a shot. How far must the nearest house be to stay within the safe limits?

$$D\sqrt{W} = 60$$

$$D = 60\sqrt{W}$$

$$D = 60 \times \sqrt{36}$$

$$D = 360$$

The nearest house must not be nearer than 360 feet and still be safe.

g. A shot design uses 10 holes of 40 pounds each. The nearest house is 720 feet away. How many holes can be shot safely per delay?

$$D\sqrt{W} = 60$$

$$\sqrt{W} = D/60$$

$$\sqrt{W} = 720/60$$

$$\sqrt{W} = 12$$

$$W = 144$$

Use up to 144 pounds per delay. Because each hole contains 40 pounds each, no more than three holes can be shot per delay. The minimum number of delay periods is four.

h. In areas where complaints are likely, it may be wise to increase the scaled distance to 100. The basic equation in this case would be:

$$D\sqrt{W} = 100$$

i. Table 5-6 gives allowable weights of explosives per delay at various actual distances for scaled distances of 60 and 100:

Table 5-6.— Weight and Distance Limits

Actual distance	Safe weight of explosives per delay at SD 60	Safe weight of explosives per delay at SD 100
10	0.03	0.01
25	0.17	0.06
50	0.69	0.25
100	2.78	1.00
250	17.40	6.25
500	69.40	25.00
1,000	277.80	100.00

*Delay must be equal to or greater than 8 milliseconds.*

j. This is a very limited discussion of ground vibration and airblast. For large blasts or continuing projects in close proximity to sensitive areas, see **Bureau of Mines Bulletin 656** or consult the Regional Blaster Examiner for direction.

k. Airblast does not contribute to the damage problem in most blasting operations. A safe blasting limit, .007 psi over pressure airblast, is recommended. This will equal to

---

128 dB on the linear peak scale and is the maximum allowed by Public Law .

l. Except in extreme cases (lack of adequate stemming, surface shots), the control of blasting procedures to limit ground vibration levels below 1.0 inches per second automatically limits overpressure to safe levels. In sensitive areas, it may be necessary to eliminate the use of detonating cord on the surface to minimize airblast.

m. Precautionary measures that will help in eliminating complaints and damages from airblast:

*1. Use adequate burden and stemming (confinement).*

*2. Blast when wind is favorable (away from structures and populated areas).*

*3. Avoid blasting during temperature inversions.*

*4. Avoid or cover surface detonating cord.*

*5. Blast during period of high ambient noise (noon).*

n. Other types of surface blasting may require the use of seismic instrumentation, especially where structures are within one mile of the blast site.

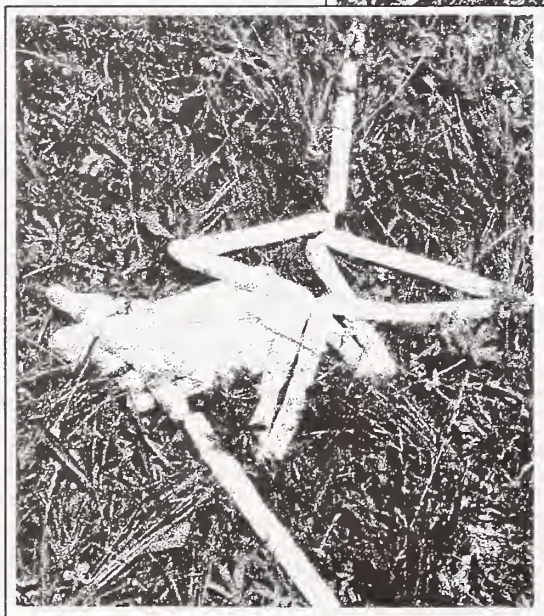
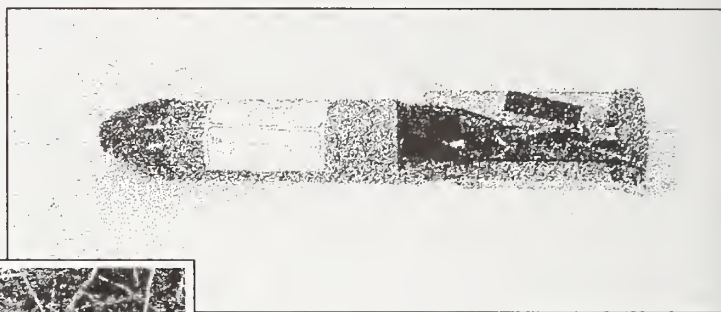
---

---

---

**Notes:**

## Chapter 6



## Chapter 6—Specialized Blasting Techniques

---

---

### *Contents*

---

6.1 Avalanche Blasting	81
6.2 Fireline Explosives	93
6.3 Burnol® Backfiring Devices	105
6.4 Seismic Blasting	107

---

Sections on techniques for blasting waterfowl potholes, fisheries improvements, stumps and ditches will be incorporated in this guide as they become available.



## 6.1 Avalanche Blasting

### Section Contents

<b>6.1 Avalanche Blasting</b>	<b>81</b>
6.1.1 Initiating Devices	81
6.1.2 Explosive Assembly	82
6.1.3 Use of Hand Charge	83
6.1.4 Cornice Control	83
6.1.5 Explosive Safety	84
6.1.6 Military Weapons	86
6.1.7 Avalauncher	89
6.1.8 Firing Procedures (Reserved)	91
6.1.9 Gunnery Training Procedures (Reserved)	91

## 6.1 Avalanche Blasting

Slope testing, avalanche release, and snow stabilization are the main objectives for using explosives in avalanche blasting. To achieve these objectives, a standard charge is used that is capable of developing detonation pressure equal to 1 KG of TNT

Several types of explosives are available that can develop the appropriate detonation pressure. By knowing the detonation velocity and the density of a given explosive, the detonation pressure can be calculated (Chapter 2 - Explosives).

### 6.1.1 Initiating Devices

Avalanche blasting is based on non-electric detonating systems or systems that are not susceptible to initiation from the high static electricity that is prevalent in snowstorms and near ridgecrests. Even with non-electric blasting caps, avalanche blasting should not be done when there is evidence of a strong static electricity field (cumulonimbus clouds, electric buzzing).

**a. Cap and Fuse.** A Cap-and-fuse assembly can detonate explosives that are sensitive to a No. 6 cap (Figure 6.1-1). However, in severe winter weather, some primers (high ammonia nitrate content) may require a No. 8 cap or larger. Blasting caps are susceptible to accidental ignition from excess heat,

friction, or static electricity and should be handled with great care. Where adverse conditions are expected (static electricity), other techniques should be used or the blasting operation should be shut down.

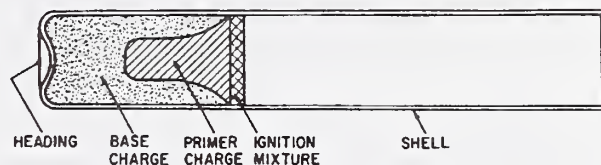


Figure 6.1-1.—Du Pont nonelectric blasting cap.

The highest quality safety fuse should be used. The fuse length depends on the time needed to escape the blasting location. Always add a margin of safety. After a new roll of fuse is purchased, a test segment should be ignited and the burning rate should be timed. Under no circumstances should a fuse be cut to a length that allows fewer than 70 seconds burning time or less than State law allows. (Times may be greater in some States).

Safety fuse should be stored, uncoiled, and assembled to the cap at room temperature under controlled conditions. Fuse should be cut squarely and inserted in the blasting cap immediately. A clean, square cut (Figure 6.1-2a) allows proper assembly. Cutting on the slant (Figure 6.1-2b) prevents seating. ***Under no circumstances shall an igniter be placed on the fuse until the charge is to be detonated.***

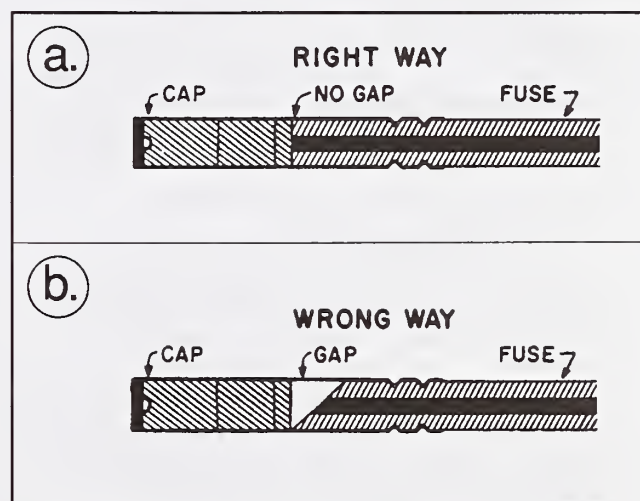


Figure 6.1-2.—Proper cap and fuse assembly.

**b. Non-Electric Detonating System (Nonel).**

This is a thin plastic shock tube that has a light dusting of reactive powder on the inside surface (approximately 1 pound per 70,000 feet). When initiated, this tube will reliably transmit a low-energy signal from one point to another by means of a shock wave phenomena much akin to a dust explosion. It will reliably detonate around sharp bends and through kinks. Because the detonation is sustained by such a small quantity of the reactive material, the outer surface of the tube remains intact during and after functioning. Nonel can be initiated by detonating cord or by a blasting cap. It will reliably initiate instant or delay Nonel blasting caps. Nonel is ideally suited for precision, non-electric delay initiation.

**c. EBW (Exploding Bridgewire).**

Exploding bridgewire detonators do not contain any primary explosive and are not detonated by stray currents, static electricity, radio transmission, or fire. A large, precisely timed electrical pulse from a special firing set is required to detonate an EBW. This firing set delivers the required electrical charge to the detonator through a maximum of 2,500 feet of hookup wire. Three detonators, the RP-80, the RP-83, and the RP-501, may be used with this system (see Chapter 3).

**c. Two-Component Explosives.**

Gelatin and cast primers are classified as high explosives and must be stored and handled according to strict codes (see Chapter 3, Explosive Storage). Because of regulations dealing with explosives security, storage is expensive. Where there is a limited need for explosives, avalanche workers may wish to avoid the more expensive storage requirements by using a two-component system. Stored separately, the components are not high explosives. They are classified as high explosives only when mixed. The storage advantage is offset by higher cost of materials, lower detonation speeds, bulkier charges, the inconvenience of mixing the explosive in the field, and the requirement of a mixing time of about 1/2-hour to bring the mixture to full strength. Mixing should be done at temperatures of 0°C (32°F) or above. Once mixed, the explosives will detonate at -50°C or lower. When using two-component explosives where the charge will be thrown, tape the cap to the container to avoid separation and misfire.

**d. General Considerations.**

As soon as the cap-and-fuse is inserted into the explosive, the system is armed. From this instant, the relatively insensitive explosive contains a sensitive cap and is vulnerable to accidental detonation. For this reason, delay arming as long as possible. Usually it is possible to arm the explosive just before tossing the charge onto the target. However, when wind and temperatures are severe, overall safety is sometimes served by arming the explosives in a shelter before starting on the control route. Under no circumstances should the ignitor be put on the fuse until just before tossing the charge.

## 6.1.2 Explosive Assembly

**a. Cast Primers.**

Cast primers are usually high-density, pressed, or cast cylinders of TNT, Pentolite, and/or other ingredients. TNT is a fast, powerful explosive that is relatively insensitive to accidental detonation by shock. It was developed by the military to withstand the rigors of the battlefield. Its fumes do not produce headaches, as do those of some other explosives; they are toxic, but this is not a problem in normal outdoor use. One disadvantage of TNT is that it leaves a messy black crater; another disadvantage is high cost. Pure TNT is not reliably detonated by No. 6 or No. 8 blasting caps, so cast primers of TNT include a more sensitive explosives, such as PETN.

**b. Gelatin Primers.**

Gelatin primers are less expensive than cast primers and do not leave a black crater. They detonate as fast as TNT but are slightly more bulky. They have a high percentage of nitroglycerin mixtures; they produce headaches, deteriorate, and are more shock-sensitive than primers that consist of, for example, TNT. Nitroglycerin begins to freeze at -29°C (-20°F) and is very susceptible to premature detonation when punched. Therefore, it should not be used near this low temperature.

**e. Arming Cast Primer.**

Figure 6.1-3 shows the steps for arming cast primers. Most cast primers are manufactured with a hole through the middle, and an off-center hole that does not go all the way through the primer. The central hole is designed to be detonated by high-explosive detonating cord. The off-center hole is usually lined with a primer, that is sensitive to a No. 6 blasting cap. It is essential to place the cap in the proper hole to avoid a misfire. In avalanche work, it is convenient to lace the fuse tightly through the central hole and then into the off-center hole, snug against the end of the hole. The assembly is then taped securely.

**f. Arming Gelatin Primer.**

The arming of a gelatin primer is shown in Figure 6.1-4. Gelatin primers have no precast holes, so it is necessary to punch two diagonal holes. First, a hole is punched through the charge with the punch end of the crimper. Then, the charge is rotated one-fourth turn, and a second hole is punched slightly deeper than the length of the cap. The

fused cap is then laced through the first hole and the cap is inserted into the second hole. The assembly is taped securely.

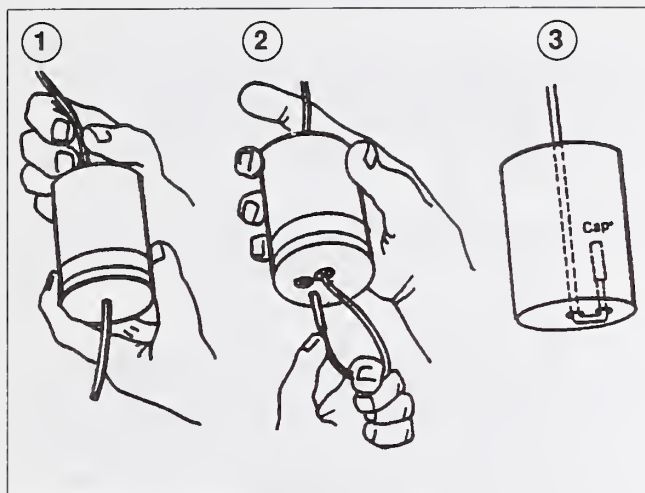


Figure 6.1-3.—Arming cast primer.

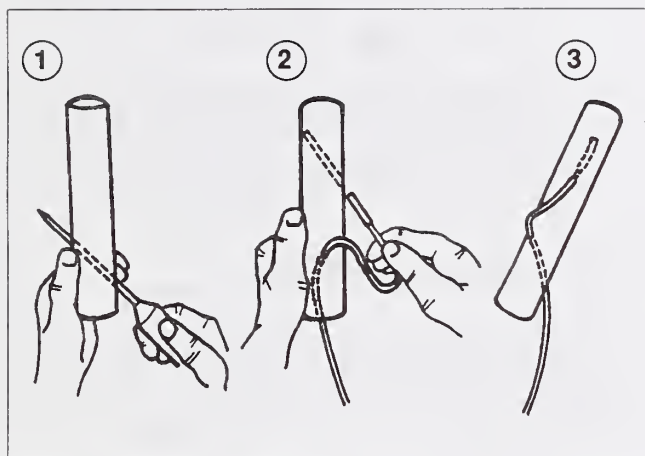


Figure 6.1-4.—Arming gelatin primer.

**7. Arming With Detonating Cord.** Explosives may be detonated with detonating cord. Charges are armed by taping the cap to the detonating cord or joining the cap and the cord with special connectors. The explosive end of the cap should point along the detonating cord, toward the main charge. A minimum of 25 grains per foot shall be used. Consult manufacture for proper size of cord. Because in both these systems the cap is exposed and vulnerable to accidental shock, make the final connection of cap and detonating cord only at the blasting position when ready to fire.

### 6.1.3 Use of Hand Charge

The prepared charge, including detonator, is carried in the control team member's pack. The person should not be loaded so heavily that skiing is clumsy. **Igniters are carried separately from the explosives.** Team members keep in constant contact using radios. Once at the blasting position;

- a. Make sure all possible runout zones are free of people and traffic. For areas not visible from the blasting point, arrange for signals from an observer.
- b. Work with only one charge at a time.
- c. Step into blasting position and make final check of target and escape route.
- d. If not pre-armed, arm the charge.
- e. Clip approximately 1 inch off the end of the safety fuse and firmly insert the fuse into the igniter. The igniter should be activated immediately. Caution: Occasionally, the act of inserting the fuse into the igniter may cause ignition before the igniter is activated.
- f. If there is no sign of ignition, reclip the end, attach a new igniter and observe if the fuse is burning. Then, place or throw the charge.
- g. Get to a safe position and await detonation.

### 6.1.4 Cornice Control

a. A simple and safe procedure for cornice blasting is to put surface charges of cast or gelatin primers, or the equivalent (ANFO or slurries) along the estimated tension line of the cornice roof. The recommended steps for cornice blasting with surface charges are:

1. Select the number of charges necessary to cover the extension line of the cornice roof adequately. Lace each charge with an 18-inch length of detonating cord, referred to as branch line.
2. Set out a trunk line of detonating cord parallel to the safe working line.
3. Set the first charge into position along the working line. Attach the branch line of the first charge to the main line with a girth hitch, clove hitch, or other approved connector.

4. In a similar manner, connect the adjacent charges on down the line until all charges are connected.

5. After connecting all branch lines to the trunk line, carefully push each charge from the working line to the presumed tension line of the cornice.

6. Align each branch line perpendicular to the trunk line.

7. Loop the end of the trunk line to form a continuous loop back to the starting point and attach the line to complete a loop.

8. After the charges are in place, tape a blasting cap-and-fuse to a 3-foot length of detonating cord. The explosive end of the cap must point down the trunk line toward the charges. Properly attach this assembly (pigtail) to the trunk line just before igniting the charge.

9. When using safety fuse, allow enough time to reach a safe area before denotation. Check with posted guards just before attaching ignitor and lighting fuse.

b. A more efficient blasting scheme is to bury the charges in a row of boreholes. In borehole cornice blasting, one may achieve satisfactory results with about half the explosive used in surface blasting. It is also possible to blast effectively with low-cost, low-detonation-pressure explosives. Although borehole blasting of cornices increases efficiency, boring holes along the presumed tension line exposes the avalanche blaster to considerable danger. Safety in borehole blasting depends critically on:

1. Blasting crew's ability to judge correctly the safe working line.

2. Feasibility of maintaining a tight, secure belay.

c. The recommended steps in borehole blasting are:

1. The driller, belayed securely, steps into position on the safe side of the working line and drills a row of holes no deeper than half the thickness of the roof. Drill boreholes as close as possible to the cornice's potential tension line.

2. Borehole diameter should allow the charges to fit as tightly as possible. Space holes as needed. Because cornice snow is normally quite hard, boring might require an auger.

3. Once holes are bored, string out the trunk line of detonating cord. To prevent loss of explosives in the event of a sudden cornice collapse, secure a free end of the main line to an anchor until the system is ready to be detonated.

4. Insert a charge attached to the branch line into the first hole. Connect the branch line to the trunk line; refill the hole with snow, and compact it lightly.

5. After preparing all boreholes this way, make a continuous loop of the trunk line and tie it to the main turn line so all charges are inside the loop. Attach a blasting cap to a 3-foot length of detonating cord. The explosive end of the cap must point down the trunk line toward the first charge. Tie this pigtail to the main line just before igniting the charge. Firing takes place after the usual check with the posted guard.

d. Because detonating cord plays an important role in cornice blasting, become acquainted with the basic techniques for working with this high explosive (See Chapter 5, *Detonating Cord* 5.2.4).

### 6.1.5 Explosive Safety

All avalanche blasting work, including storage, transportation, and handling of explosives, must comply with all laws.

#### a. General

1. An avalanche should not be released artificially until the avalanche path, including the potential runout zone, is cleared of people.

2. Position avalanche guards at the entrance to the path if there is any chance that people will enter the path during blasting.

3. During unstable conditions, artificial release of one avalanche may trigger sympathetic release over a wide area. Consider such possibilities and clear the appropriate area.

4. Always handle explosives with utmost care.

**b. Personnel**

1. Each avalanche control team shall consist of a qualified and licensed blaster and at least one trained assistant.

2. All members of the blasting team should be in good physical and mental condition and should be competent ski mountaineers. They shall all be equipped with electric transceivers and other safety gear as required (probe, ski poles, shovel).

3. All members of the blasting team shall be properly trained and qualified.

4. Responsibility for the preparation and placement of the charge shall not be divided. The blaster-in-charge is responsible for supervising all phases.

5. All members of the blasting team shall be able to communicate with each other at all times during a blasting operation.

**c. Explosives**

1. Explosives should have a shelflife in normal storage of at least one operating season.

2. Explosives should not be packaged in metal containers.

3. Explosives should have excellent weather resistance.

4. Use non-shock, sensitive explosives.

5. Explosives shall be stored in an approved magazine.

**d. Detonation Systems**

1. The detonation system should be as simple as possible. Recommended systems consist of explosive, EBW caps, non-electric detonating system, or fuse caps and ignitors.

2. Caps shall be protected fully from external shock during control maneuvers.

**e. Preparation of Detonating System**

1. To prevent misfires, the detonator assembly shall be properly attached to the explosive charge.

2. Charges shall be armed with caps as late as possible in the blasting operation.

**f. Firing of Charge**

1. If using fuses, ignite only one fuse at a time. (Double fusing is an unnecessary complication.)

2. Immediately place or throw the charge.

**g. Placing Charge From Control Route**

1. Place or throw the charge down onto the target from a safe position, preferably a ridge, then, retreat to a safe position.

2. In cases where the charge could slide down on a hard snow surface, it must be belayed or anchored.

**h. Tossing Charges from Ski Lifts and Trams**

1. The number of charges tossed from lifts and trams shall be kept to an absolute minimum. (May not be allowed in some States).

2. The lift or tram crew shall be informed of the blasting operations.

3. Affected slopes and turnout zones shall be cleared prior to blasting operations.

4. The lift or tram crew shall stand by in full readiness for emergency procedures (transfer of lift to auxiliary power, evacuation, etc.).

5. Only the blasting crew and the essential operating personnel shall be on the lift or tram.

6. When the charge is tossed, the lift or tram must be moving upslope. The charge must be tossed downslope and to the side.

7. Charges shall not exceed 4 pounds of TNT equivalent.

8. Fuses must be cut so that blasting crews have moved on the lift at least 300 feet from the target by the time of detonation. Fuse length shall comply with State law or be a minimum of 70 seconds.

9. All chairlift, tram, and gondola cars should be at least 300 feet from the target at time of detonation.

10. Precautions must be taken to avoid tossing a charge into any of the lift equipment: moving chairs, cables, lift towers, etc.

#### **i. Retrieving Misfires**

1. A conscientious effort must be made to retrieve each misfire.

2. If conditions make it impossible to retrieve the misfire, the slope should be closed and a search begun. Slope shall remain closed until a reasonable effort has been made to retrieve the misfire. If not found, record the probable location. Record as much information as possible to aid in retrieving the charge at a later date.

3. The blasting crew must wait at least 15 minutes before approaching any misfire. Note: Some State regulations may be longer. A misfire aflame or emitting smoke must be left alone.

4. The normal procedure is to disarm and retrieve the charge and then to escape to an avalanche-free location.

5. Deviation from the normal procedure (for example, planting a second charge next to the misfire) depends on the cause of the misfire, the sensitivity of the explosive, and the location of the charge.

(d) *Does not use alcohol to excess.*

3. The written examination covers the safety of weapon use and the handling, transporting, and storage of ammunition.

4. In the oral examination, the applicant must demonstrate an overall understanding of safety rules for military weapons, firing techniques and principles.

5. Applicants must demonstrate in a field exercise, or in a mock field exercise, the ability to handle ammunition and to set the ammunition for loading, aiming, and firing. They must demonstrate actions to take in the event of a misfire, cookoff, and a dud.

6. From the results of the written examination, the oral examination, and the field exercise, the Regional examiner or a designee determines if the candidate is fully qualified. Applicants not fully qualified but, who have not been eliminated, will be placed in an in-training category until experience and skills have been obtained. They will then be reexamined for certification. The in-training category is gained only through the certification process.

7. Certificates must be renewed every 3 years. Renewal will be under the same conditions as the issuance of the original certificate.

8. A yearly refresher course shall be given to all personnel who use military weapons.

9. Certificates can be suspended at any time by the Forest Supervisor, or upon the recommendation of the Regional examiner to the Forest Supervisor. Suspensions will be made when safety violations have occurred or when evidence exists that there is a lack of skill. To regain certification, a suspended employee must pass the exams and field exercise and be recertified by the Regional examiner.

10. Each Region shall have a Standard Operating Procedure (SOP). This SOP shall be approved by the Regional Examiner or a designee.

#### **b. Military Ammunition Storage**

1. Military ammunition storage facilities shall be fireproof, weatherproof, bulletproof, and theft-resistant. All aboveground facilities must be constructed to conform with the requirements for

### **6.1.6 Military Weapons**

#### **a. Certification For Use**

1. All employees who will use military weapons must be certified every 3 years by the Regional Blaster Examiner. A Regional military weapon and ammunition certification training session will be held for this. Certification is based on the results of written and oral examinations and a practical field exercise.

2. In addition, applicants must meet these requirements of the *Organized Crime Control Act of 1970*:

(a) *Be over 21 years of age.*

(b) *Has never been indicted or convicted for any crime punishable by imprisonment for a term exceeding 1 year.*

(c) *Does not use unlawful drugs.*

lightning protection found in the current edition of the *National Fire Protection Association Standard No. 78*.

2. Ammunition may be stored in approved magazines cordwood style (that is, piled so they touch each other in their original cardboard tube or other type of original packing cover) only. The minimum distance from the magazine to inhabited buildings, highways, ski lifts, and designated ski runs is 800 feet for 75 mm and 1,200 feet for 105 mm and 106 mm ammunition. These minimum distances provide reasonable protection from flying fragments (See *Chapter 3 Storage*).

### 3. Aboveground Storage

(a) Magazine storage buildings for ammunition only must meet the minimum requirements as described in *ATF Explosive Laws and Regulations (ATF p. 5400.7) dated 10/91 or the latest edition, subpart k - Storage, section 55.207 with the following exceptions:*

(1) The interior of the magazine does not need to be constructed of a non-sparking material.

(2) Only outdoor facilities shall be used, all doors shall be constructed of 3/8-inch steel plate and lined on the inside with 2 inches of hardwood.

(b) Ammunition may be stored above ground at less than 800 and 1,200 feet from inhabited buildings, highways, ski lifts, and designated runs if facilities are designated to resist mass detonation and to provide directional control of blast and fragments.

(c) For magazines with 12-inch thick, reinforced concrete walls and roof, or with 3 feet of earth cover against the walls and with the access door in the roof, the following apply:

	Minimum Round Separation Inches	Fragment Hazard Distance Feet
75 mm M-48 and M-309 HE	0 <sup>1</sup>	40
75 mm M-349 HEP-T	3.00	40
105 mm M-323 HE	4.00	60
105 mm M-326 HEP-T	4.75	60
106 mm M-346 A1 HEP-T	5.00	60

<sup>1</sup> "Winerack" not required; can be stacked cordwood fashion.

(d) The minimum round separation may be provided by a "winerack" fabricated from concrete or concrete pipe or from tubing with sand as a separating medium. Materials other than these may be used for "winerack" construction, providing they have been approved by and have been tested to the satisfaction of the Forest Service. The cost of such testing is the responsibility of the permittee. Cardboard tubes shall be completely contained within the winerack except that the primer end may stick out approximately 1 inch for ease in removing the tube from the winerack.

(e) Where magazine access doors are in the sidewalls, 800 feet and 1,200 feet must be used as a fragment hazard distance in the direction the door faces for 75 mm and 105 mm ammunition respectively. This distance is necessary, unless barricades or other means reduce the fragment hazard distance. Directional control of airblast and fragments can be achieved by designing a weak wall or roof (usually by placement of the access door) or by strengthening the walls with earth.

(f) Location and design of the storage facility must consider the fragment hazard distance and the potential damage from the airblast of an explosion.

(g) When the access door is in the roof, fragments are projected through this weak point in the the roof and fall back to earth close by, while fragments projected through a sidewall access door travel a greater distance because of horizontal velocity.

(h) The following thicknesses of cover or embankment are considered adequate to provide protection against fragment throw (this criteria should be used in areas where fragment throw cannot be permitted in certain directions):

	Earth cover Feet	Hard Rock or concrete Feet
75 mm M-48 and M-309 HE	3.99	3.38
75 mm M-349 HEP-T <sup>1</sup>	5.27	4.35
105 mm M-323 HE <sup>1</sup>	5.80	4.75
105 mm M-326 HEP-T <sup>1</sup>	7.50	6.0
106 mm M-346 A1 HEP-T	7.60	6.05

<sup>1</sup> Must be in an approved winerack to limit detonation to a single round.

## 4. Underground Storage

(a) Ammunition may be stored underground, cordwood style, at less than 800 feet (75 mm) and 1,200 feet (105 mm) minimum distance, if the following formulas are used to determine the depth of cover required as protection against fragment throw:

- (1) Hard, unfractured rock or concrete:

$$D = 3W^{0.30}$$

- (2) Earth, fractured or soft rock:

$$D = 3.5W^{0.33}$$

Where:  $D$  = cover thickness in feet and

$W$  = explosive filler weight of TNT in pounds.

(b) HEP-T ammunition has an explosive filler of Comp A3 and the filler weight must be multiplied by a factor of 1.35 to obtain the equivalent TNT filler weight. The explosive filler weight  $W$  is the sum of the weights of filler in the total number of rounds to be stored in the facility.

(c) The depth of overburden arrived at by using these formulas is considered adequate against debris throw, except in the direction in which the explosion is vented. The blast areas must be clear of buildings, highways, roads, ski lifts, designated ski runs, and other inhabited facilities for 800 feet for 75 mm and 1,200 feet for 105 mm ammunition. This cover should be used in areas where debris throw cannot be allowed in certain directions.

(d) The minimum distance from tram towers, terminals, ski lift towers, inhabited buildings, and other items that could be damaged by shock waves or airblast from an explosion must be considered on an individual basis. Minimum distances shall be determined as described in the interim change to DOD 6055.9, Chapter 9, "Quantity—Distance Standards for Underground Storage."

(5) Tables 6.1-1 through -4 give the number of rounds, total pounds of explosives, and amount of cover required to eliminate debris throw for various ammunition using hard rock or earth cover. This is adequate to eliminate debris throw, except in the direction of the access door.

Table 6.1-1.—

75 mm M-349 HEP-T  
2.55 lbs Comp A3  
TNT equivalent 3.45 lbs.

No. of Rounds	TNT Lb	Hard Rock Ft	Earth Cover Ft
100	345	17.32	24.07
200	690	21.32	30.26
300	1,035	24.08	34.59
400	1,380	26.25	38.04
500	1,725	28.06	40.95
600	2,070	29.64	43.48
700	2,415	31.05	45.75
800	2,760	32.31	47.82
900	3,105	33.48	49.71
1,000	3,450	34.55	55.47

Table 6.1-2.—

105 mm M-323 HE  
461 lbs. TNT

No. of Rounds	TNT Lb	Hard Rock Ft	Earth Cover Ft
100	461	18.89	26.49
200	922	23.26	33.30
300	1,383	26.26	38.07
400	1,844	28.63	41.86
500	2,305	30.61	45.06
600	2,766	32.34	47.85
700	3,227	33.87	50.35
800	3,688	35.25	52.61
900	4,149	37.69	56.64

Table 6.1-3.—

105 mm M-326 HEP-T  
7.5 lbs. Comp A3

No. of Rounds	TNT Lb	Hard Rock Ft	Earth Cover Ft
100	1,010	23.90	34.32
200	2,020	29.43	43.14
300	3,030	33.23	49.31
400	4,040	36.23	54.22
500	5,050	38.74	58.37
600	6,060	40.91	61.98
700	7,070	42.85	65.22
800	8,080	44.60	68.16
900	9,090	46.21	70.86
1,000	10,100	47.69	73.37

Table 6.1-4.—

106 mm M-346 A1 HEP-T  
7.72 lb. Comp A3  
TNT Equivalent 10.4 lb

No. of Rounds	TNT Lb	Hard Rock Ft	Earth Cover Ft
100	1,040	24.22	34.65
200	2,080	29.69	43.55
300	3,120	33.52	49.79
400	4,160	36.55	54.75
500	5,200	39.08	58.93
600	6,240	41.27	62.59
700	7,280	43.23	65.85
800	8,320	44.99	68.82
900	9,360	46.61	71.55
1,000	10,400	48.11	74.08

**c. Weapon Security.** Discourage theft of avalanche-control weapons by:

1. Removing vent assembly, firing pin, breech, or similar part of the weapon after firing sequence and storing in the ammunition storage magazine or other similarly locked facility.
2. Removing guns from firing stand and storing in locked facility at the end of the avalanche season.
3. Securing weapon to mount during firing season.

## 6.1.7 Avalauncher

### a. Assembly of Rounds

1. Gather the necessary components to assemble enough rounds for mission (primers, caps, fin assemblies, nose cones).
2. Round preparation should be done in a controlled environment.
3. Prior to assembly, count out an equal number of fin assemblies, primers, caps, and nose cones.
4. Round assembly
  - (1) *Inspect primer for correct cap well depth, diameter and for pieces of pentolite in cap well.*
  - (2) *Inspect fin assembly making sure all parts are present. Check for any irregularities in fin assembly.*
  - (3) *Inspect nose cone of primer for proper seating.*
  - (4) *Hold fin assembly in upright position and place cap on nipple, making sure it seats properly.*
  - (5) *Lower primer over cap and seat in fin assembly. Avoid "forcing" the primer over the cap.*
  - (6) *If assembled rounds are transported, do so with caution. Prior to transport, package rounds so they remain in a stable position.*

### b. Tower Procedure:

1. Clear tower of snow and inspect all equipment.
2. Check range of swivel on avalauncher and adjust braking mechanism used for locking swivel.
3. Quickly release valve on nitrogen bottle to be used and expel a quick blast of gas to insure a clear opening free of foreign matter. Check threads on bottle for ice.
4. Inspect male gas hose coupling for ice and other obstructions.

5. Prime vessel until flagger valve closes:

(a) Check barrel for ice and assemble into loading tray.

(b) Check that "match marks" on barrel are in correct position in relation to loading tray.

(c) Check vessel for gas leaks. If there is a leak, do not fire the avalauncher until the leak has been fixed.

6. Test fire unloaded avalauncher at 50 psi.

#### c. Loading

1. Keep number of personnel and ammunition in the area to a minimum.

(a) Single gunner missions are permissible. However, all steps in this procedure shall be followed.

2. Loading:

(a) Done in "horizontal position" or at "elevation position."

(b) Check that safety valve is in the "on" position.

(c) Prime vessel until flapper valve closes (50 lb standard)

(d) Site avalauncher to proper deflection for desired shot.

(e) Slide barrel out of loading tray and lock in position for loading.

(f) Visually inspect that projectile is properly assembled. Place the round in the loading tray, making sure it is properly seated. Remove the cotter pin for the assembly and retain so as to keep track of rounds fired..

(g) Slide barrel down into loading tray—check that "match marks" on barrel are in correct position in relation to loading tray.

#### d. Firing

1. A "safe" first shot (i.e. registered round) must be fired on each mission to indicate if there is any variance in normal weapon behavior.

(a) Shot pressures should be kept above 65 psi to ensure the removal of base plate/arming pin by air friction as round leaves the barrel.

(b) For firing missions involving new platforms, new terrain or new targets, gunners should gather data by aiming low and gradually work shots into desired location.

2. Firing

(a) Raise avalauncher to proper elevation if applicable.

(b) Fill pressure vessel to desired pressure and double check pressure with data.

(c) Recheck deflection and elevation.

(d) Gunner calls out "All Clear."

(e) Gunner calls out "ready to Fire."

(1) Release safety valve

(f) Gunner calls out "Fire"

(1) Gunner presses trigger valve down to fire.

(g) Gunner observes projectile flight to observe discrepancies in trajectory and point of impact in case of dud.

(h) Close trigger and safety valve.

(i) Prime pressure valve until flapper valve closes (50 lbs)

3. Post firing mission record:

(a) Date and time

(b) Who fired the avalauncher

(c) Shot numbers fired upon, pressure, elevation, and results.

---

(d) *Wind and temperature*

(e) *Record all duds and any probable causes.*

(f) *Any additional comments pertinent to mission; i.e., maintenance needs, round flights, etc.*

4. Projectiles with fuses shall not be retrieved but destroyed in place.

### **6.1.8 Firing Procedures (Reserved)**

### **6.1.9 Gunnery Training Procedures (Reserved)**

---

---

**Notes:**

## 6.2 Fireline Explosives

### Section Contents

<b>6.2 Fireline Explosives</b>	<b>93</b>
6.2.1 General	93
6.2.1.1 Advantages of Fireline Explosives	93
6.2.1.2 Disadvantages of Fireline Explosives	93
6.2.2 Fireline Explosives	94
6.2.2.1 PETN Explosive Cord	94
6.2.2.2 Water Gel Explosives	94
6.2.2.3 Emulsions	95
6.2.2.4 Safety Tests	95
6.2.3 EBW Detonator and Firing Set	96
6.2.3.1 EBW Detonator	96
6.2.3.2 Control Unit	96
6.2.3.3 Firing Module	98
6.2.3.4 Lead Wires	98
6.2.4 Procedures	98
6.2.4.1 Communications	98
6.2.4.2 Layout Procedures for Fireline Explosives	101
6.2.4.3 Detonator Connection Sequence	101
6.2.4.4 Fire Module Hookup Sequence	102
6.2.4.5 Hookup of the Control Unit	103
6.2.4.6 Post-Fire Procedures	103
6.2.4.7 Misfire Procedures	103
6.2.4.8 Other Considerations	104

## 6.2 Fireline Explosives

### 6.2.1 General

Fireline explosives are linear explosives that enable crews to construct firelines under certain conditions much faster and with less environmental impact than conventional methods. The quality of line constructed varies from a nearly finished line in light brush or grass fuels to a lower quality line than required in heavy brush and slash fuel types. However, even in heavy brush and slash the cleaning action of explosives can enhance access and effectiveness of fire crews who finish the line.

All fireline explosives are tested by the Bureau of Mines to insure that they will not accidentally detonate in conditions found in the field. They are impact tested to

insure that they will not detonate when paracargoed even if the parachute fails to deploy. They will not detonate when shot with a 30 caliber projectile and they will not mass detonate if accidentally caught on fire. Only those fireline explosives that pass the tests and that are accepted on the qualified products list can be used for this activity. In conjunction with fireline explosives, the exploding bridgewire detonator (EBW) system is exclusively used to insure the safest system for building firelines.

#### 6.2.1.1 Advantages of Fireline Explosives

As labor and overhead costs rise, fireline blasting offers real time savings. Smaller crews may be used to suppress fires because less cutting and/or digging handline is required, particularly in heavy fuels or ground cover. Increased speed of building the line can save wildland resources. Sometimes smaller crews equipped with explosives can be delivered to a fire faster than larger, conventionally equipped crews. Other advantages include:

*Brush and other debris (fuel and slash) are scattered rather than piled next to the finished line.*

*Mineral soil in the line is loosened and easy to dig for use in hotspotting and mop-up.*

*A fine layer of soil dusts fuels close to the line and acts as a retardant.*

*Blasting is generally more environmentally sound than using hand tools or dozers.*

*Fireline explosives can be paracargoed into extremely remote locations.*

#### 6.2.1.2 Disadvantages of Explosives

Use of explosives for fuels management or wildfire projects can be limited by lack of adequate explosive storage facilities.

Personnel using fireline explosives must be carefully selected and thoroughly trained.

Transportation and handling demand special precautions.

## 6.2.2 Fireline Explosives

Fireline explosives are typically a minimum of 50 to 70 feet long, range from 1-1/4 inch to 1-1/2 inch in diameter, and weigh about 60 to 70 pounds when supplied in a cardboard box. Fireline explosives are made and sold as follows:

*PETN explosive cord supplied by Ensign-Bickford*

*Water gel supplied by IRECO or ETI Companies*

*Emulsion supplied by Austin Companies.*

*Note: PETN explosive cord is typically rigid compared to water gel and emulsion and does not conform to the ground very well. The latter two explosives are very flexible. No end connectors are provided on any of the explosives, so ends are taped (attached) together to ensure propagation from one length to the next. Note that all fireline explosives are Class A explosives.*

### 6.2.2.1 PETN Explosive Cord

PETN explosive cord contains enough high explosive to effectively blast most fuels and enough cooling salts to prevent fire starts. The cord is relatively heavy so a balance must be struck between performance and weight.

Two production versions of the explosive cord are available: a 7-strand and a 4-strand version (Figure 6.2-1). The 7-strand cord contains enough explosive to effectively blast fireline in most fuels. The 4-strand cord is less effective from a blast standpoint, but weighs less and is cheaper by the foot.

PETN cord detonates at about 21,000 feet per second at temperatures well below 0 degrees F.

Both versions of the explosive cord come packaged in a fiberboard box measuring 20-3/4 inches by 21-1/2 inches by 12 inches. Each box contains approximately 100 feet of the 7-strand cord, which weighs about 71 pounds, or 175 feet of the 4-strand cord, which weighs about 70 pounds.

PETN has an indefinite shelf life.

### 6.2.2.2 Water Gel Explosives

Water gel explosives are a slurry type explosive packaged in 50-foot or longer plastic tubes and are supplied on cardboard reels (Figure 6.2-2).

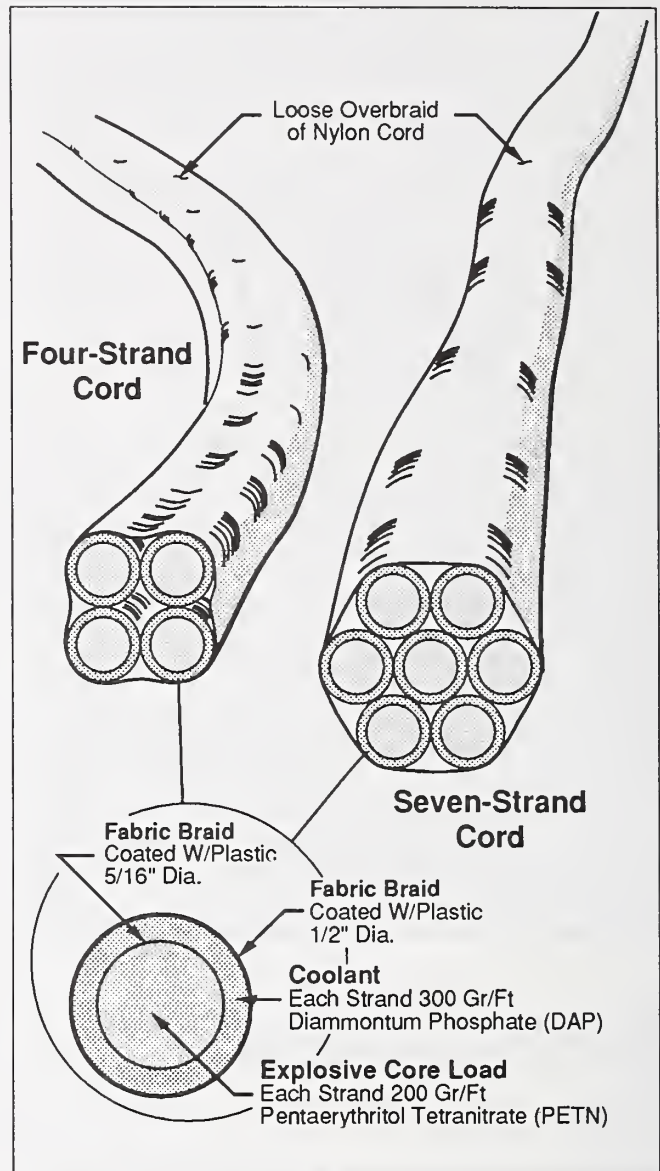


Figure 6.2-1.—Cross section of PETN explosive cord.

Water gel explosives consist of oxidizing salts, fuels, and sensitizers dissolved or dispersed in a continuous liquid phase. The entire system is thickened and made water-resistant by the addition of gellants and cross-linking agents. The oxidizing salts are usually selected from ammonium nitrate or calcium nitrate. Aluminum, gilsonite, and oil are frequently used as fuels. Sensitization may be provided by chemical sensitizers such as the nitrate salts of organic amines, nitrate esters of alcohols, perchlorate salts, or small particles of aluminum. Physical

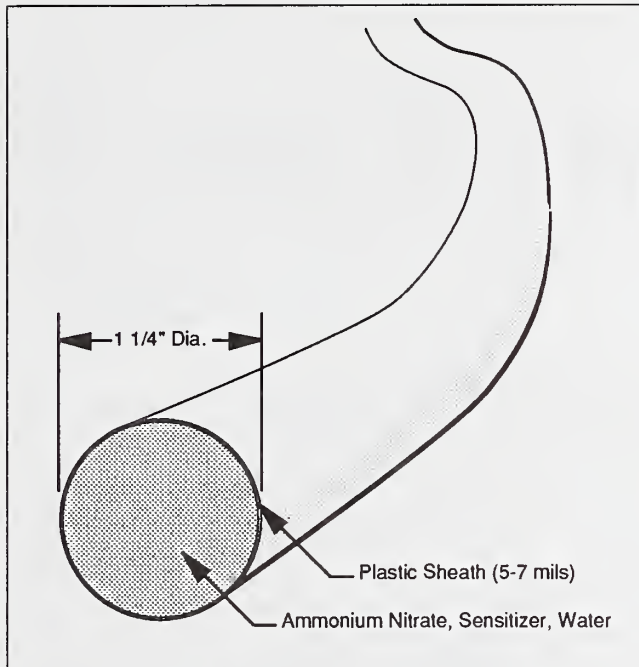


Figure 6.2-2.—Construction of a typical water-gel explosive tube.

sensitization may be provided by entrapped air bubbles, either alone or in combination with chemical sensitizers.

Water gels are Class A explosives that detonate at a speed of from 15,000 to 18,000 feet per second. Water gels will **not** detonate consistently at temperatures below 40 degrees F.

The shelf life of water gel is about 1 year although some manufacturers are reporting shelf life as high as 5 years.

#### 6.2.2.3 Emulsions

Emulsions are packaged in plastic tubes, however, they are not typically supplied on reels.

Emulsions are the first commercial explosive manufactured with all liquid oxidizers and liquid fuels. The liquid oxidizers are dispersed as microscopic droplets in the liquid fuel. The result is a very intimate mixture of these components leading to a vastly improved "intimate reaction zone" and a more complete and efficient reaction.

With most emulsion formulations there is very little change in their viscosity at ambient temperatures down to 10 degrees F and they will typically

detonate at temperatures down to 0 degrees F. They do thin out at temperatures above 100 degrees F.

The shelf-life and stability of emulsion explosives is excellent with no change in their explosive properties after 1 year. (Storage times can exceed 2 years.)

Emulsions are Class A explosives that detonate at a speed of about 15,000 to 18,000 feet per second.

#### 6.2.2.4 Safety Tests

The seven-strand fireline cord was originally tested by the Naval Weapons Center at China Lake, California. The cord was subjected to bullet impact, burning, crushing between caterpillar tread and rocks, chopping with an ax on rock, dragging over rough ground, air drooping 500 to 1,000 feet, bending, and exposure to retardant—all with no indication of possible hazard. Note, however, that even though safety tests indicate that the cord can be burned, etc., without detonating, there is no guarantee that detonation will not occur.

Water gels (slurries) include both cap-sensitive and non-cap-sensitive products. A significant advantage of water gels is that they are reliably sensitive to conventional priming methods, yet significantly more resistant to accidental detonation from abusive impact, shock, or fire. When subjected to an open flame, water gels will burn but not detonate. In a test conducted by the Canadian Government, an enclosed truck containing 5 tons of water gel did not detonate when burned. Water gels will not detonate when shot with a 30.06 projectile. Users should, however, recognize that water gels are explosives, and should be treated as such. While specific tests indicate that water gels are relatively safe, severe shocks, such as higher velocity bullets can detonate these products.

Emulsions do not utilize explosive sensitizers, and in reality do not become an explosive until after the addition of "microballons" or air voids. For this reason, emulsions are perhaps the safest explosive, other than water gels, in terms of flame, impact, and friction resistance. Emulsions fail to detonate from impact and friction tests used as the standard throughout the industry, including the bullet impact test. Independent studies done to determine at what severe conditions explosives will detonate, clearly show emulsions have a higher degree of resistance to detonation from impact

than either slurries or dynamites. However, emulsions are explosives that are designed to detonate. The relatively safe emulsions demand respect and the proper handling requirements afforded to all explosives.

Safety testing of all approved fireline explosives is conducted by the Bureau of Mines, Safety Testing Laboratory, Pittsburgh, Pennsylvania. These tests are designed to show that approved fireline explosives meet or exceed the safety characteristics of the seven-strand PETN cord.

### 6.2.3 EBW Detonator and Firing Set

The FS-9 Exploding Bridgewire (EBW) firing system (Figure 6.2-3) is designed to generate and deliver an electrical energy pulse to reliably fire exploding bridgewire detonators (EBW). Electric blasting caps (EBC) are not used with this system. The FS-9 EBW firing system is to be exclusively used with fireline explosives.

#### 6.2.3.1 EBW Detonator

The EBW detonator (Figure 6.2-4) is an alternative to the common electric blasting cap. While similar in construction, the EBW detonator is characterized by the exclusive use of secondary explosives that will not detonate when exposed to heat, friction, fire, static electricity, low voltages, or radio transmission. EBW detonators are rated "Class C" explosive and have less restrictive shipping regulations than conventional blasting caps. EBWs, however, are required to be stored in the same way as conventional caps.

#### 6.2.3.2 Control Unit

The purpose of the FS-9 control unit (Figure 6.2-5) is to provide low voltage (40 volts DC) electrical energy to the firing module and to insure a safe and reliable operation sequence for the firing of the EBW detonators. This output occurs when both the "Hold-to Arm" and "Hold-to-Fire" buttons are simultaneously pressed and the shunting plug is mated into the control unit "Safety Interlock" connection. The "Battery OK" lamp will illuminate

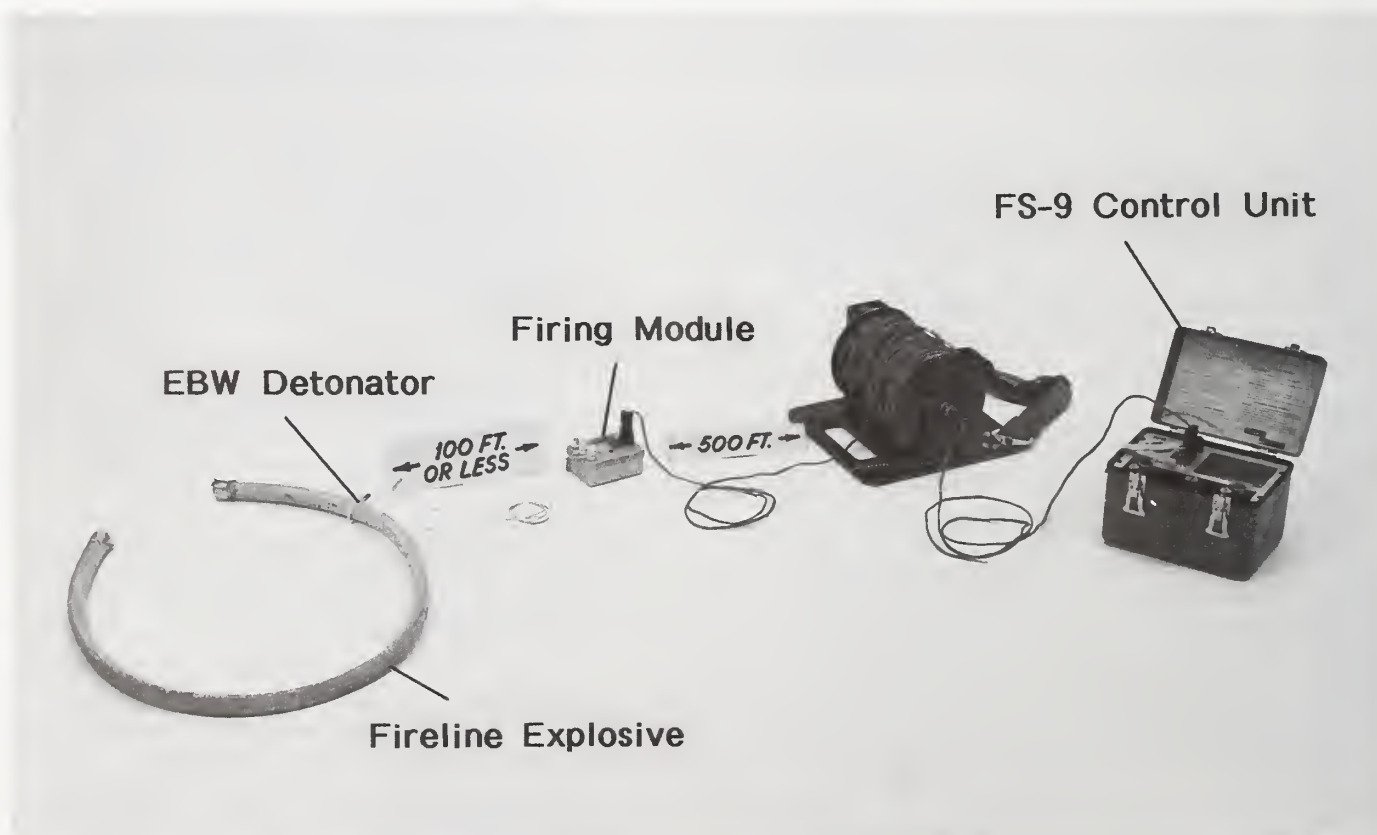
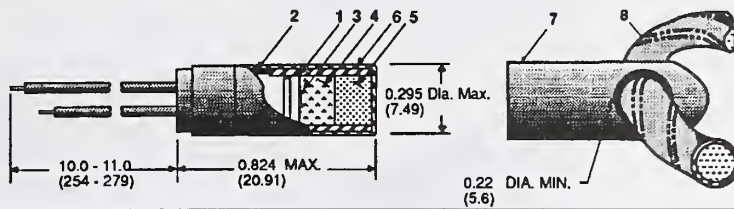


Figure 6.2-3.—Exploding bridgewire firing system.

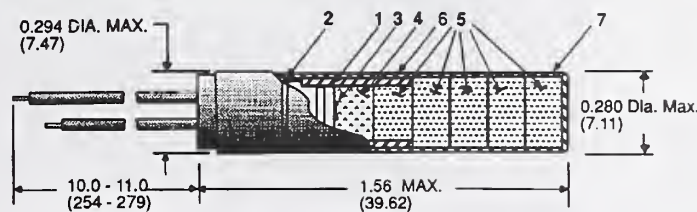
### RP-80 EBW Detonator



#### Parts Description

1. Molded Head: FM #4005 Phenolic.
2. Brass Sleeve
3. Gold Bridgewire: 0.0015 inches diameter, .040 inches long.
4. Initiating Explosive: 80 mg of PETN.
5. Output Explosive: 123 mg of RDX with binder.
6. Cup: .007 inches thick aluminum.
7. Plastic Adapter: with hole for 50 gr/ft cord.
8. Detonating Cord: (not included).

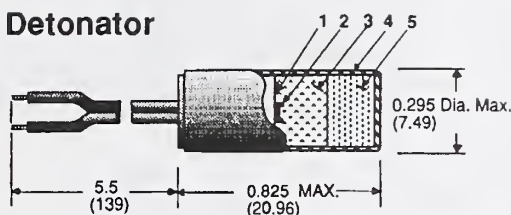
### RP-83 EBW Detonator



#### Parts Description

1. Molded Head: FM #4005 Phenolic.
2. "O" Ring
3. Gold Bridgewire: Gold, 0.0015 inches diameter, .040 inches long.
4. Initiating Explosive: 80 mg of PETN.
5. Total Output Charge: 1031 mg of RDX with binder (13.5 grains @ 1.55 - 1.70 gr/cc density).
6. Aluminum Cup: .007 inches thick aluminum.

### RP-501 EBW Detonator



#### Parts Description

1. Molded Head
2. Gold Bridgewire: 0.0015 inches diameter, .040 inches long.
3. Initiating Explosive: 136 mg of PETN.
4. Output Explosive: 227 mg of RDX with binder.
5. Cup: .007 inches thick aluminum.

Figure 6.2-4.—EBW detonators.



Figure 6.2-5.—FS-9 control unit.

when the "Hold-to-Arm" button is pressed, only if the batteries are above 32 volts. When the "Hold-to-Fire" button is pressed in conjunction with the "Hold-to-Arm" button, the voltage is then applied to the output terminals and the "Ready lamp" will illuminate. At this time the firing module, if connected, will begin arming and automatically fire within 2 to 8 seconds. To abort the firing while arming is taking place, merely release the "Hold-to-Arm" or "Hold-to-Fire" or both buttons before detonation occurs. The FS-9 control unit consists of the following items:

- a. A shorting plug that precludes arming of the system until mated to the control unit "Safety Interlock" connection.
- b. Dual pushbutton or toggle switches for firing.
- c. Ready-to-fire lamp indicator
- d. Internal batteries for supplying the electrical energy.

- e. A battery charger that operates from 110 volts AC line voltage
- f. A battery check lamp allowing verification of adequately charged batteries.
- g. A sealed case for carrying and transporting the firing system.
- h. Fuse to protect the system circuitry.
- i. Wire screw plugs for wire connection.

### 6.2.3.3 Firing Module

The firing module (Figure 6.2-6) is separated from the control unit so the operator can detonate the charge at extended distances (500 feet) as required by the size and characteristics of the main explosive charge. The input to the FS-9 module must be between 32 and 40 volts. This input charges a one microfarad capacitor. When this energy storage capacitor reaches 3,000 volts, it is discharged across the "To EBW Detonator Only" terminals of the firing module. By mating the shorting plug to the "Discharge" connection, the energy storage capacitor is completely and immediately discharged, thus precluding inadvertent arming of the firing module and detonation of the EBW detonator. The firing module consists of a completely sealed metal box which includes:

- a. Binding posts for connecting the input wires from the control unit.
- b. A voltage conversion system to increase the input voltage to approximately 3,000 volts to insure proper function of the EBW detonator.
- c. An automatic trigger system that discharges when the module contains sufficient energy to fire the detonator (3,000 volts, 1,500 AMPS).
- d. An internal discharge capability if a misfire or abort should result.
- e. An external shorting capability across the energy storage capacitor by using the same connector or shorting plug as used at the control unit "Safety Interlock" connection.
- f. Binding posts for connecting the output wires to the detonator.



Figure 6.2-6.—FSI-9 Firing Module.

### 6.2.3.4 Lead wire

Duplex strand solid core 18- or 20-gage wires are used as primary and secondary lead wires. The secondary lead wire is a minimum of 500 feet long and a maximum of 2,500 feet long. The primary lead wire is a maximum of 100 feet long. The wire should have a slick, tough insulating coat.

## 6.2.4 Procedures

### 6.2.4.1 Communications

The Blaster-In-Charge will plan communications with a designated blasting team regarding:

*Safety,  
Layout and firing procedures,  
Location of guards and/or flaggers,  
Length of explosive that can be safely  
guarded and controlled.*

The blasting team should have a clear channel while in actual operations. Each team member should have a radio.

The Blaster-In-Charge must brief the team to insure good communications. Some suggested points to be covered are:

**a. Packers (packers are also typically guards).**

Discuss various methods of explosive deployment.

Do not throw boxes of fireline explosives or handle roughly.

Prior to blasting and hookup of each fireline segment to be blasted, a final check on deployment will be made by the Blaster-In-Charge or the assistant blaster.

**b. Guards (typically also packers).**

Assign each guard a number (guard #1, guard #2).

Indicate where each guard is to be located and **be sure** they know the location (minimum of 500 feet from firing line, see Figures 6.2-7 and 6.2-8.)

Cover radio and/or verbal communication techniques that will be used, including the number each guard uses.

Guards should have a good vantage point for observing and listening around the blasting area.

Guards should not stand under snags, in heavy brush areas, or in slide area.

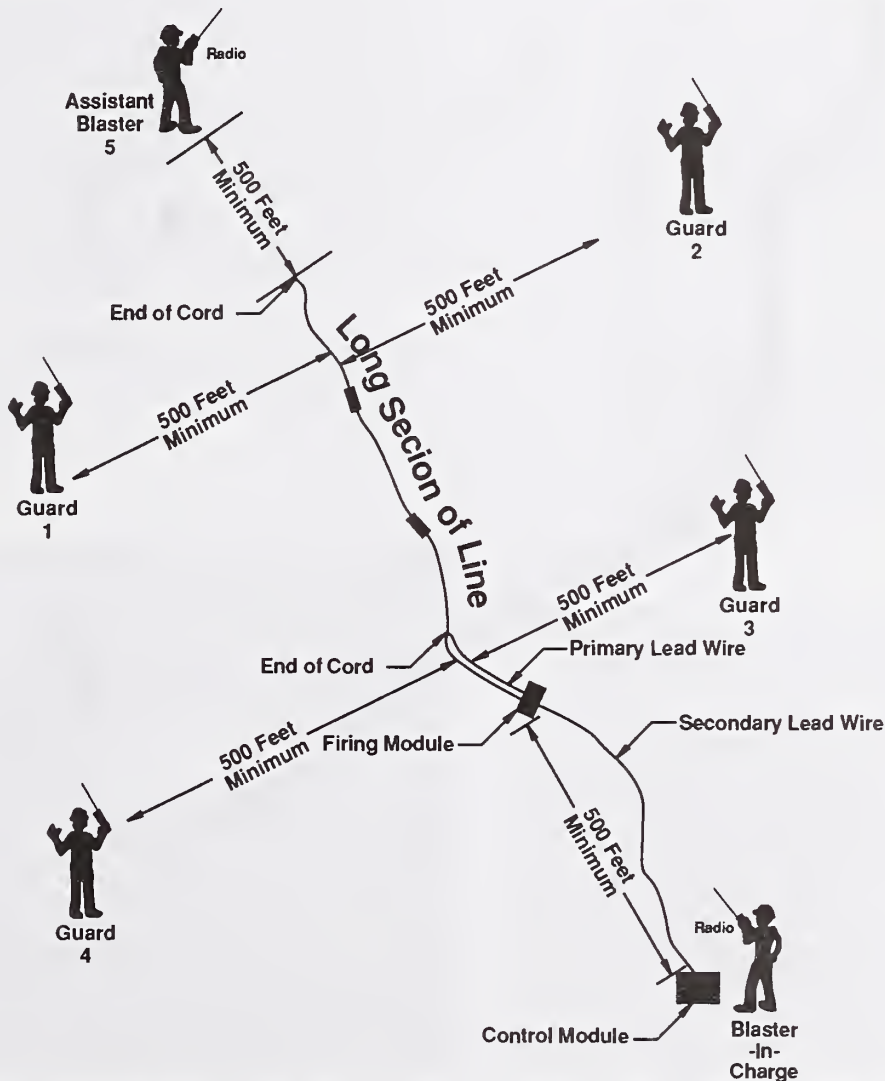


Figure 6.2-7.—Example of explosive layout and placement of guards. (Guards are numbered by Blaster-In-Charge.)

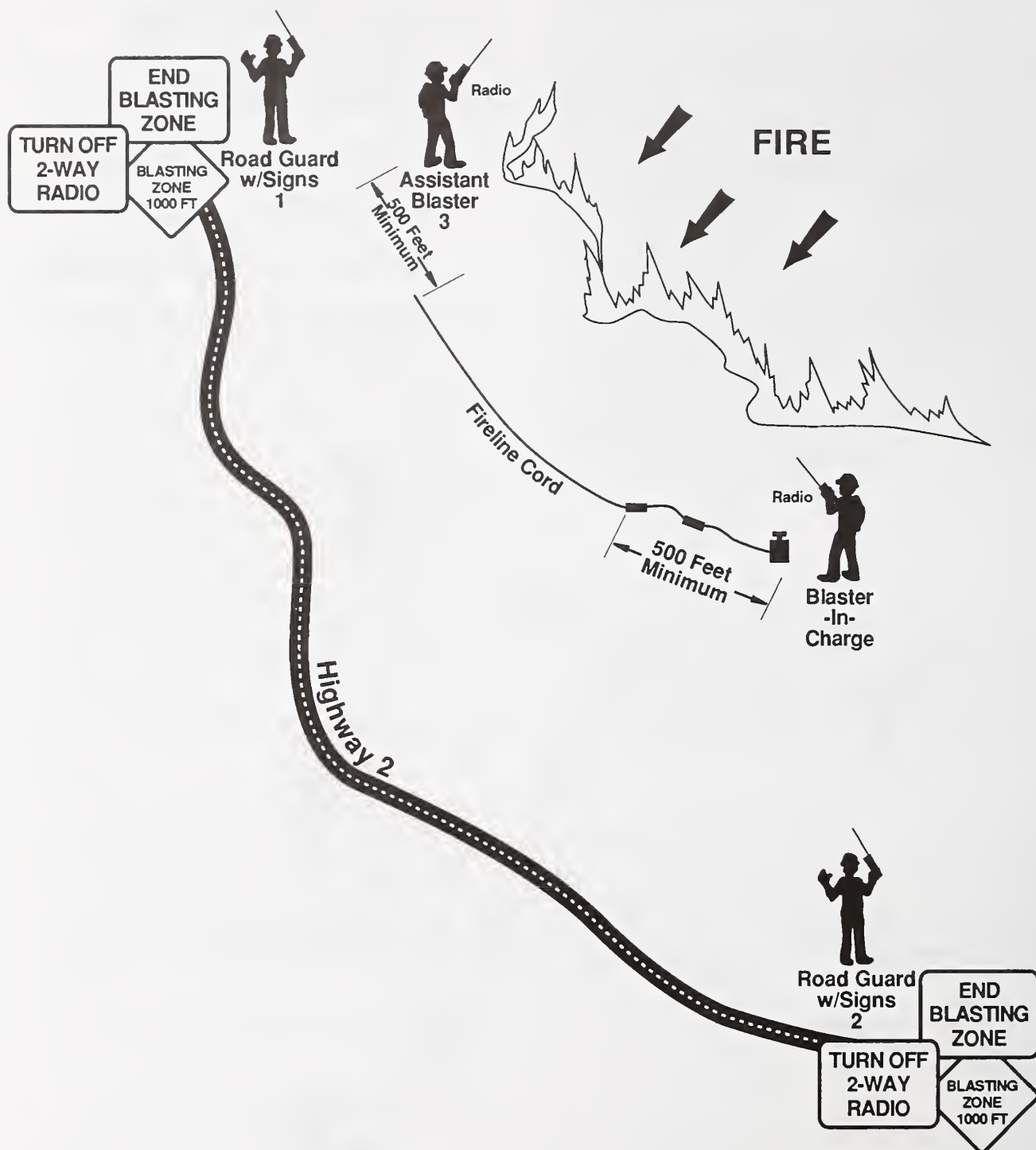


Figure 6.2-8.—Example of placement of guards when blasting close to roads or any public facility. (Guards are numbered by Blaster-In-Charge.)

Guards should not return to the blasting area until the “All Clear” is given by the Blaster-In-Charge.

Guards should watch the horizon for flying objects and select an object (tree, rock) as shelter if necessary.

Guards must stop the blasting sequence if **at any time for any reason** they deem it unsafe.

#### 6.2.4.2 Layout Procedures for Fireline Explosives

The Blaster-In-Charge must have all EBW detonators and the control unit under personal control during all blasting operations.

There are two methods of deployment: 1) The carton or reel of explosives can be carried and the end of the cord held stationary, or 2) The carton or reel can be held stationary and the cord pulled from the reel or box. After deployment, the ends of adjacent cords are overlapped 6 inches to 8 inches and attached (taped) together (Figure 6.2-9). When properly attached, any number of cords can be fired with a single detonator. The number of cord lengths per blast or shot will be determined by the Blaster-In-Charge.

The explosive is most effective when placed on or near the ground and under downfall. Large logs can be sawed, wrapped with the explosive, or left for later sawing.



Figure 6.2-9.—Splice on fireline explosive.

After the explosives are placed, either the Blaster-In-Charge or the primary assistant should insure that the cord is properly positioned, and all joints are securely taped, tied, or clamped together.

The assistant blaster should then move to a position at least 500 feet beyond the end of the fireline cord. The Blaster-In-Charge must also be at least 500 feet from the charge.

The assistant blaster and any guards shall be a minimum of 500 feet from the explosive and guard the area from all intruders from any direction. Guarding the area is most critical to the safety of the operation, because inadequate guarding is the most common cause of explosive-related accidents.

The Blaster-In-Charge must positively determine that all guards are properly placed, all other crew members are in a safe area, and that the blasting zone is clear of all personnel for at least 500 feet. **Care should be exercised when selecting safe areas to insure adequate protection from flying objects, falling rocks, tree limbs, and objects that might ricochet.**

#### 6.2.4.3 Detonator Connection Sequence

Check the continuity of the secondary lead wire (low voltage) with the galvanometer. This is done by stripping about 2 inches of insulation from the wire, shorting one end of the lead wire, and touching individual wires at the other end to the poles of the galvanometer (See Figure 6.2-10).



Figure 6.2-10.—Galvanometer and case.

The EBW detonator lead wire need not be shunted during shipping or while performing the hookup procedure.

Check the continuity of the EBW detonator with the galvanometer.

Connect the detonator to the primary high voltage) lead wire. (This is done by placing a lead wire and a detonator wire parallel to one another, then making a loop.)

Check with guards by radio; if safe to continue, yell "Fire in the hole" or "Fire One" (first call).\*

*\*In Alaska and some other locations "Blasting one," "blasting two," and "blasting now" are substituted for "Fire In the Hole" or Fire One."*

Attach the detonator to the explosive. (This is typically done by inserting the cap into the explosive with the end of the cap pointed in the direction that the explosive was deployed, Figure 6.2-11.) When using the RP-80 directional detonator and 7-strand detonator cord, place the detonator perpendicular to the fireline explosive (Figure 6.2-12). Tape the detonator into place so it cannot be dislodged, or tape securely to outside. Be sure that the wire leads do not touch each other or any other materials such as leaves and grass. Move to the module.

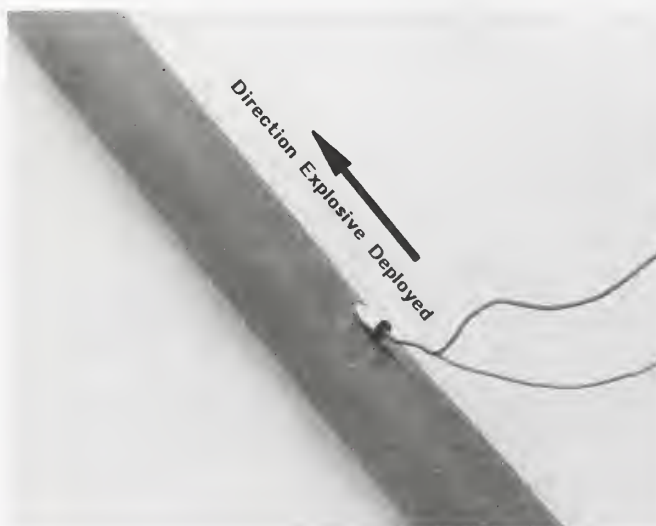


Figure 6.2-11.—Detonator inserted in water gel.



Figure 6.2-12.—RP-80 placed perpendicular in 7-strand detonator cord.

#### 6.2.4.4 Firing Module Hookup Sequence

Insert the shunting plug into the "safety interlock" connection of the module. This creates a short circuit in the system and also drains off any electricity that may have built up in the module.

Check the continuity of both primary and secondary lead wires before connecting them to the firing module.

Connect both lead wires to the module. (These can be erroneously connected backwards so carefully examine the module. The yellow side reads, "To EBW Detonator ONLY." The black side reads, "To Control Unit.") Screw plugs are provided to make the connection.

Check with guards by radio; if safe to continue, yell, "Fire in the hole" or "Fire Two" (second call).

Remove the shorting plug. check to see that leads are not shorted.

Move to the control unit. (Be sure to take the shunting plug ).

#### 6.2.4.5 Hookup of the Control Unit

Connect the secondary lead wires coming from the firing module to the FS-9 control unit. (There are two wire screw plugs where these will be connected.)

Check with guards by radio: if all clear, yell “Fire in the hole” or “Fire Three” (third and final call).

Insert the shunting plug into the safety interlock provided on the control unit. (Shunting plug **must** be plugged in or the entire system will not work.)

Depress the “Hold to Arm” button. The “Battery OK” light should illuminate within 2 seconds.

Simultaneously activate the “Hold to arm” switch and “Hold to Fire” switch. When both are activated the “ready” light will illuminate. Detonation will occur from 2 to 8 seconds from the time both switches are activated.

#### 6.2.4.6 Post-Fire Procedures

Remove the shunting plug from “Safety Interlock” connection on the control unit. This renders the control unit inoperable.

Call the end guard at the far end of the line. Tell the guard to check that end to see if detonation was complete. **Note: the end guard is the only other person, besides the Blaster-in-Charge, cleared to enter the blast site at this time.**

Disconnect the lead wires from the terminal marked “To Firing Module” at the control unit. Short the lead wires together for future electrical continuity checks and move to the firing module. Be sure to take the shunting plug.

Insert the shunting plug into the “Safety Interlock” connection on the firing module. This renders the firing module inoperable and bleeds off any excess electricity.

Disconnect the lead wires from the terminals marked “To Control Unit” at the firing module

Disconnect lead wires from the terminals marked “To EBW Detonator Only” and move to the fireline.

Check to make sure all the explosives have detonated and check with guard at the far end of the line to confirm that all of the explosives detonated at that end.

Radio all guards that it is clear to enter the blasting area.

If the guard on the far end of the line finds undetonated explosives, keep all personnel out of the area and notify the Blaster-In-Charge. The Blaster-In Charge will walk the line and determine why the explosive did not detonate. If it was caused by an improper connection, attach a new cap to the end of the explosive and detonate it using the same procedures previously outlined. If the explosive is burning, clear the area and wait until it has burned out. Before proceeding, the end guard will secure the approval of the Blaster-In-Charge and check again to be sure it is clear before allowing the crew to return.

#### 6.2.4.7 Misfire Procedures

In the case of a misfire, the detonator received either insufficient energy or an energy pulse with an incorrect rise time or frequency pulse. On rare occasions it may be a faulty detonator. If the initial energy pulse is insufficient to break the bridgewire, the detonator may not be accidentally detonated. It is safe to handle immediately and is not hazardous in this condition. The only possible hazard is the fireline explosive. Once it has been established by the Blaster-In-Charge that it is safe to proceed to the explosive, the following procedure should be used:

Remove the shunting plug from the “Safety Interlock” connection at the control unit.

Recheck the batteries and fuse. If the fuse is blown, the wires between the control unit and the module could be shorted. Correct this condition,, replace the fuse, and restart the firing procedure.

If this is not the case, disconnect the wires at the control unit from the terminals marked “To Firing Module” and shunt them so the continuity can be checked at the firing module.

Return to the firing module with the blasting galvanometer and shunting plug.

Mate the shunting plug into the safety interlock connection.

Disconnect wires at the firing module from the terminals marked “To Control Unit” and check for continuity. If continuity is not indicated, determine

where the wires are broken and repair or replace. Then, restart the firing procedure.

Disconnect wires at the firing module from terminals marked "To EBW Detonator Only" and check for continuity. If continuity does not exist, the electrical pulse did not reach the detonator and either the lead wires are broken or the detonator is faulty. Shunt the lead wires at the firing module.

Return to the detonator. Disconnect the detonator and check continuity of both the detonator and lead wires. Replace either item if continuity is not indicated.

During this procedure, if all components appear normal, replace the detonator and the primary lead wire from the detonator to the firing module. The most likely cause of a failure is within the twin lead wires because of the high voltage of the firing pulse.

An additional check may be performed on the primary wire. If the insulation is damaged on the wire from the firing module to the detonator, the firing pulse may arc across these points or to ground causing an insufficient energy pulse to reach the bridgewire in the detonator.

It is a good practice to check both the secondary and primary lead wires for breaks when coiling them. When setting up, the blaster can let the wire run through either hand while walking along the line. Breaks in the insulation can often be felt in this manner, then repaired or replaced.

#### 6.2.4.8 Other Considerations

If a portion of the explosives did not detonate, and if it is not threatened by fire, cut off any mangled or otherwise damaged explosive material and attach it snugly to the good cord a foot or more from the cut end. Place a new detonator in the cord and go through the firing procedure.

If for some reason it is impractical to shoot a failed portion of explosive material, it can be placed in one of the original boxes and returned to the magazine. If this is done, be sure to make the person in charge of the magazine aware of it.

If you have explosives in a vehicle on a return trip, be sure to leave the explosives placards in place.

If you have no explosives other than detonators, placards **must** be removed from the vehicle before starting the return trip.

Remember to return any remaining explosives including detonators to an approved magazine, and see that any needed corrections are entered in the magazine inventory.

Maintain a shot log or blasting record showing the date and time of each blast and the amount and type of explosive used. (See page 10)

## 6.3 Burnol<sup>1</sup> Backfiring Devices

### Section Contents

<b>6.3 Burnol<sup>1</sup> Backfiring Devices</b>	<b>105</b>
6.3.1 General	105
6.3.2 Storage	105
6.3.3 Transportation	105
6.3.4 Use Procedures	105

## 6.3 Burnol<sup>1</sup> Backfiring Devices

### 6.3.1 General

a. Burnol backfiring devices (Figure 6.3-1) consist of a metal canister of gelled flammable material and a cap, fuse, and ignition system with additional ignition material in a plastic container around the cap.

b. Burnol is a useful burning tool, but it has an explosive device (blasting cap). It is potentially hazardous if misused. Because these devices are commonly used by fire management personnel who do not normally work with explosives, it is very important that they be properly trained in the safe use of the product.

### 6.3.2 Storage

a. **Storage of Cap-and-Fuse Assembly.** Ignitor shall not be installed on cap-and-fuse assembly in storage.

b. **Permanent Storage.** Storage shall be in accordance with *Chapter 3* of this guide. Storage must be in a type 1 or 2 magazine and inspected once every 7 days.

c. **Temporary Storage.** With road access, Burnol backfiring devices must be stored in a type 3 magazine and must be attended. Without road access, store in accordance with *Chapter 3*.

d. **Grenade Features.** Ignitor shall not be installed on the fuse before shipment. Shunted cap and fuse assembly shall be used.

### 6.3.3 Transportation

a. Transportation shall be in accordance with *49 CFR* and *Chapter 4* of this guide.

b. Vehicle shall be driven by qualified driver as defined in 4.2.1, and shall not be left unattended.

c. Cap and fuse assembly shall be in portable magazine or IME container.

d. Vehicle shall be placarded only when transporting more than 1,000 devices.

e. Vehicles transporting explosives shall be equipped with two 10-BC or larger fire extinguishers.

### 6.3.4 Use Procedures.

a. Users shall be certified Forest Service blasters. (See *FSM 6170*).

b. Cap and fuse shall be installed on the device at the work area.

c. The ignitor shall be installed on the fuse at the shot point when the user is ready to throw the device.

d. The user shall install the ignitor, activate it, and throw it immediately.

e. Misfires will not be retrieved for at least 15 minutes.

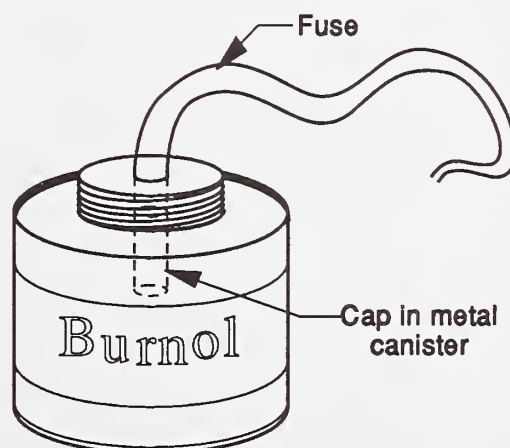


Figure 6.3-1.—Burnol backfiring device armed.

<sup>1</sup>Burnol is a registered trademark of J.S. Brower & Associates, Inc., 2040 North Tower Avenue, Pomona, CA 91767.

**Notes:**

## 6.4 Seismic Blasting

### Section Contents

<b>6.4 Seismic Blasting</b>	<b>107</b>
6.4.1 General	107

## 6.4 Seismic Blasting

### 6.4.1 General

In all respects, seismic blasting shall conform to the same requirements as construction blasting, including storage and transportation of all explosive materials, charge preparation, and detonation. When small buried charges are used, distances between the firing set and the charge may be reduced if written approval is obtained from the Regional Forester. This approval shall state the charge site and composition, depth of burial, and minimum distance allowed.

No surface-charges or above-surface charges shall be left unattended. Loaded shot holes will not be left unattended or unprotected. A protected hole shall be one that has been loaded so the charge cannot be removed and the legwires made inaccessible or concealed. Protected holes will be shot within one week of loading. Under no circumstances will any explosives be abandoned on the line.

"Blasting" signs will be posted on roads and trails to notify forest users of blasting activities. All signing for blasting operations shall conform to the *Manual of Uniform Traffic Control Devices* (See Chapter 5).

Explosives magazine sites shall be approved prior to any seismic operations (See Chapter 3).

**Notes:**

NATIONAL AGRICULTURAL LIBRARY



1022349279

10

NATIONAL AGRICULTURAL LIBRARY



1022349279